

# A REVISION OF SOME ORDOVICIAN GRAPTOLITES OF EASTERN NORTH AMERICA

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**ABSTRACT.** In a study of part of Hall's type material, lectotypes are proposed for *Climacograptus bicornis* (Hall) and *Climacograptus spiniferus* Ruedemann; the variation in the proximal end of the latter is amply illustrated and discussed; it is also suggested that the latter may be the slightly modified descendant of the former. *Climacograptus parvus* Hall (= *C. phyllophorus* Gurley) is considered to be conspecific with *Pseudoclimacograptus scharenbergi* (Lapworth) and *Orthograptus amplexicaulis* (Hall) is revised and the question of its priority over *Orthograptus truncatus* (Lapworth) is considered.

In a review of part of Ruedemann's type material, the types of *Climacograptus eximius* Ruedemann are interpreted as consisting of deformed specimens of *Pseudoclimacograptus modestus* (Ruedemann) and of *Climacograptus brevis strictus* (Ruedemann); *Climacograptus tenuis* Ruedemann is considered to be conspecific with *Climacograptus pygmaeus* Ruedemann; *Climacograptus lorrainensis* Ruedemann is assigned to *Glyptograptus*, and the name *Climacograptus putillus* (Hall) is temporarily restricted to the types in the American Museum of Natural History. *Corynoides calicularis* var. *americana* Ruedemann is revived and raised to specific rank as *Corynoides americanus*; the types of *Corynoides comma* Ruedemann are interpreted as deformed individuals of *Corynoides americanus* or *C. calicularis sensu lato*.

The systematic treatment is preceded by a review of the Middle–Upper Ordovician zonation hitherto recognized in the graptolite succession of eastern North America which is strongly provincial, containing faunas unknown outside this part of the continent. The zonation is extended downward with the addition of the *Diplograptus multidentis* and *Nemagraptus gracilis* Zones and expanded with data gathered since it was first proposed (Riva 1969).

THIS is a partial revision of a few of the graptolites first described by James Hall in volume 1 of the *Paleontology of New York* (1847) and of others described later by Ruedemann (1908, 1912, 1925, and 1947) from the Ordovician of New York; it includes some of the first graptolites recognized in North America. The Hall species discussed herein are all of widespread occurrence, but because of inadequate descriptions, figures, and, perhaps, revisions, they have been misunderstood by many specialists in this field. The Hall collections have remained untouched for many years; in fact they were last studied by Ruedemann (1908) at the beginning of this century. No holotypes or lectotypes have ever been selected; many type collections are mixed, consisting of specimens belonging to other species or contain specimens used by subsequent authors to erect new species without separating them from the original collections. The Ruedemann collections must also be approached with care, for his type material is often of a mixed nature and some of his species are really conspecific with, or variants of, other species. Others, again, have been considered synonymous with other species, but in reality they have been found to be fully valid and are redescribed. It should be kept in mind here that Ruedemann's descriptions, especially his dimensions, do not always correspond to reality.

This study has been expanded with the aid of collections from the type locality or from strata correlative with it. An effort has always been made to trace and recollect from the type locality except where it has been rendered inaccessible or it has disappeared under a highway.

The systematic discussion is preceded by a brief discussion of the biostratigraphic framework hitherto recognized in the graptolite succession of the Middle and Upper Ordovician of eastern North America which is characterized in part by provincial faunas unlike those of other parts of North America and Europe.

#### GRAPTOLITE BIOSTRATIGRAPHY OF THE MIDDLE AND UPPER ORDOVICIAN OF EASTERN NORTH AMERICA

Regional studies have been carried out in the past ten years in order to construct a graptolite zonation which reflected the strongly provincial faunas of the Middle and Upper Ordovician of eastern North America (Riva 1968, 1969). These studies continue those begun long ago by Rudolf Ruedemann (1947, p. 52), but largely on the basis of the incomplete Ordovician of New York. The Taconic Orogeny began to affect the eastern part of North America in mid-Ordovician time causing the formation of Appalachian land masses west of which endemic graptolite faunas developed. These faunas are strikingly dissimilar from those of the Pacific faunal province of western and south-western North America and those of northern Europe. The faunal succession and zonation previously proposed for the autochthonous Canajoharie-Utica Shales of eastern North America and the Upper Ordovician of Anticosti Island (Riva 1969) is here extended downward to include the *D. multidentis* Zone, the existence of which has recently been documented in Appalachian allochthonous units, and the widespread *N. gracilis* Zone, which is believed to correlate with the Porterfield Stage, or the Black River Group, in terms of stratigraphy.

Bergström and Drahovzal (1972) have recently reported the discovery in the southern Appalachians of Llandeilo and Llanvirn faunas referable to the *G. tertiusculus* and the *D. murchisoni* Zones. In 1972 the writer discovered a typical late Llanvirn fauna in the Stanbridge slates of southern Quebec and Vermont, and just now, 1973, he has identified Llanvirn graptolites in a collection from the Hamburg Klippe of south-eastern Pennsylvania. These discoveries represent a significant breakthrough in understanding the graptolite succession of eastern North America, for up to now Llanvirn and, possibly early Llandeilo, faunas were known only from western Newfoundland (Morris and Kay 1966; Erdtmann 1971) and scattered localities in the northern Appalachians.

The graptolite zonation constructed by Berry (1960) on the basis of the graptolite succession of the Ordovician of Texas can be applied only with difficulty to the Ordovician outside the Ouachita Geosyncline. Some reasons are: (1) the Texan graptolite succession belongs to the Pacific faunal province and contains none of the Middle-Late Ordovician faunas endemic to north-eastern North America; (2) some extensive gaps seem to exist in the Texas succession, corresponding to most of the Llanvirn and Llandeilo and parts of the Caradoc and Ashgill in terms of the British succession; (3) graptolites are not common in the late Middle and Upper Ordovician of Texas as a careful examination of the data presented by Berry (op. cit.) shows; and (4) western graptolite successions are, in the writer's experience (Riva 1970), much more varied and complex than those of Texas, suggesting the need of a separate biostratigraphic scale for that region. The Texas graptolite zones have been called the 'North American Graptolite Zones' by Berry (1968), who, however has since

recognized the existence of faunal provincialism in north-eastern North America (1970b) and of a 'scarcity of certain graptolites at some horizons' in western successions (1971). North American graptolite successions cannot be simply expressed in terms of one 'standard' zonation, but a distinct biostratigraphic scale will have to be constructed in each major region in order to take fully into consideration its typical faunas and faunal provinces. Thus the task of erecting trustworthy zonal successions in the Ordovician of North America has but just begun.

TABLE 1. Middle and Upper Ordovician graptolite zones of eastern North America with a suggested correlation with those of Britain

AMERICAN SERIES and STAGES		Eastern North America	Texas (Berry, 1960)	British Isles (Skevington, 1969)	BRITISH SERIES
UPPER ORDOVICIAN		<i>C. prominens-elongatus</i>	No fauna		ASHGILL
		<i>D. complanatus</i>	<i>D. complanatus</i>	<i>D. anceps</i> <i>D. complanatus</i>	
		<i>C. manitoulinensis</i>	? ? ?		
MIDDLE ORDOVICIAN	Utica	<i>C. pygmaeus</i>	<i>O. quadrimucronatus</i>	<i>P. linearis</i>	CARADOC
		<i>C. spiniferus</i>	<i>O. 'intermedius'</i>		
	Canajoharie	<i>O. ruedemanni</i>	No fauna	<i>D. clingani</i>	
		<i>C. americanus</i>			
	Barneveld				
Wilderness	<i>D. multidentis</i>		<i>D. multidentis</i>		
Porterfield	<i>N. gracilis</i>	<i>C. bicornis</i> and <i>N. gracilis</i>	<i>N. gracilis</i>		

Listed below are the graptolite faunas characterizing each of the zones shown in Table 1 together with the lithologic units containing them. These faunal lists are approximate as many forms are in need of revision. This zonation should not in any way be considered final or unchanging. It is only the biostratigraphic framework recognized up to the present time and will be modified, changed, further divided, or simplified as data accumulate. This zonation is correlated with the Texan zonation and a revised British zonation.



*The N. gracilis Zone.* This zone is universally recognized and constitutes one of the bases for international correlations. It contains a complex and varied fauna with horizontal didymograptids such as *D. sagitticaulis*, *D. serratulus*, *D. subtenuus*; *Dicellograptus divaricatus*, *D. sextans* and varieties; *N. gracilis*, *N. exilis* and varieties; *Dicranograptus ramosus*, *D. spinifer*, *D. rectus*, *D. contortus*, *D. diapason*, and *D. furcatus*; *Orthograptus calcaratus* and varieties; *Pseudoclimacograptus scharenbergi*, *P. s. stenostoma*, *P. angulatus* (large form), and *P. modestus*; *Climacograptus bicornis*, *C. bicornis tridentatus*, and *C. brevis strictus*; *Reteograptus geinitzianus*, *Cryptograptus tricornis*, *Glossograptus ciliatus*, *Lasiograptus pusillus*, *Leptograptus flaccidus tentonensis*; *Glyptograptus teretiusculus* and *G. euglyphus*; *Amplexograptus* sp.; *Corynoides pristinus* and *C. calicularis*, as well as *Dictyonema* and a few dendroids. This fauna occurs in the Mount Merino Chert and Shale, the Austin Glen Greywacke of New York, and in lithologically similar, if not identical, rocks of the northern Appalachians to the eastern end of Gaspé, in a thrust slice of the Cloridorme 'Formation' of Gaspé, in the lower Quebec City Formation, the lower Magog slates, the Stanbridge Formation of southern Quebec, part of the Hamburg Klippe of south-eastern Pennsylvania, and part of the Athens Shale of the southern Appalachians. In Table 1, the *bicornis* and *gracilis* zones of Texas are shown as one zone because data presented by Berry (1960) from the Woods Hollow Shale shows that these zones are really based on the same fauna.

*The D. multident Zone.* This zone contains a fauna similar to that of the *D. multident* Zone of Britain and for this reason the zonal name is maintained. Collections from this zone contain some elements ranging up from the *N. gracilis* Zone such as *Climacograptus bicornis*, *C. bicornis tridentatus*, *C. brevis strictus*, *Pseudoclimacograptus scharenbergi*, *P. modestus*, *Hallograptus mucronatus*, *Reteograptus geinitzianus*, varieties of *Orthograptus calcaratus*, *Dicranograptus rectus*, *D. contortus*, *Glyptograptus teretiusculus* and *G. euglyphus*, and a few *Dicellograptus divaricatus* but it lacks the didymograpti, nemagrapti, and most of the dicellograpti of that zone, as well as other less striking or common forms. New elements of this zone are: *Dicranograptus nicholsoni*, *Diplograptus multident*, *D. compactus*, *Cryptograptus insectiformis*, and an abundance of *Corynoides* referable to *C. calicularis* s.l. This fauna was previously referred to as the 'Magog' fauna (Riva 1968). Graptolites of this zone occur through most of the Quebec City Formation, the upper part of the Magog, part of the Cloridorme 'Formation' of Gaspé; in New York they occur in parts of the Snake Hill Shale of Ruedemann, the 'Mount Merino' Formation of the southern part of that state (Offield 1967), and possibly in the upper Austin Glen Greywacke. The writer has recognized this fauna in collections from Middle Ordovician slates of eastern Pennsylvania, and Ruedemann (1947, pp. 79, 86) has reported it from the base of the Martinsburg Shale of Maryland.

No section has yet been found showing the faunal passage between the *multident* and the succeeding *C. americanus* Zone: *multident* Zone graptolites normally occur in allochthonous or Appalachian sequences and *americanus* Zone graptolites characterize autochthonous or parautochthonous sequences. An indication as to the nature of this passage is given by the graptolites found at the very base of the Macasty Shale in the L.P.G.L. core from Anticosti Island (Riva 1969, pp. 534-537), the basal part of Canajoharie Shale near Amsterdam in the lower Mohawk Valley, New York, and from uncontrolled slices of Snake Hill Shale just above the mouth of the Mohawk River at Waterford, N.Y. These units uniformly yielded *Lasiograptus harknessi*, a new small *Diplograptus*, *Orthograptus calcaratus basilicus*, *O. amplexicaulis*, *Glyptograptus euglyphus*, *Corynoides* cf. *C. calicularis*, and *Climacograptus brevis-mohawkensis* transients. These forms, all together, belong to neither the *multident* nor the *americanus* Zones, although a few elements span both zones. A recent (late 1972) collection from a Snake Hill slice a few miles above the mouth of the Mohawk River in New York contained a new spinose *Climacograptus*, long, strongly curved *Corynoides*, and *Orthograptus calcaratus basilicus*, all of which could represent a still lower level of this passage fauna. A solution of this problem awaits even more diagnostic collections.

*The C. americanus Zone.* In this zone most elements of the *N. gracilis* and *D. multident* Zones have disappeared with the exception of *Corynoides calicularis* s.l., which occurs in profusion, *Climacograptus brevis strictus*, *Orthograptus calcaratus basilicus*, and an occasional *Glyptograptus euglyphus*. The thin and short *Corynoides americanus* occurs in great numbers near the base of the zone together with *Lasiograptus harknessi*, *Orthograptus amplexicaulis*, and *Climacograptus brevis*. New elements making their first appearance halfway up the zone are *Orthograptus quadrinucronatus mucronacanthus cornutus*, *Climacograptus caudatus*, *Cryptograptus insectiformis*, and *Neurograptus* cf. *margaritatus*. *Climacograptus mohawkensis* (= *C. minus* of Elles and Wood) and *Orthograptus ruedemanni* appear in profusion near the top of the zone. This fauna characterizes the lower Canajoharie of New York and Quebec, the lower Macasty Shale



of Anticosti Island, part of the Cloridorme 'Formation' of Gaspé, part of the flysch and wildflysch sequence (St. Germain Complex) in front of the Appalachian allochthon in Quebec, and part of the Snake Hill Shale of Ruedemann in New York, and marks the beginning of provincialism in eastern North America connected with the events accompanying the Taconic Orogeny and the rise of Appalachian lands. This provincialism is more fully developed in the *C. spiniferus* Zone where European and Pacific forms appear to be in a minority.

*The O. ruedemanni Zone.* [The name *O. ruedemanni* replaces the name *C. minimus* previously given to this zone (Riva 1969) since Strachan (1969, pp. 191-193) has shown that the latter name was originally given to a Silurian graptolite.] The fauna of this zone is distinguished from that of the *C. americanus* Zone by the absence of all *Corynoides* and the almost exclusive development of two small graptolites, *O. ruedemanni* and *C. mohawkensis*, often in synrhabdosomes. *Orthograptus quadrimucronatus micracanthus*, *Cryptograptus insectiformis*, and *O. amplexicaulis* pass through this zone to the *C. spiniferus* Zone and succeeding zones; *Neurograptus margaritatus* occurs sparingly. This fauna characterizes upper Canajoharie Shales, parts of the Snake Hill Shale of Ruedemann, the Cloridorme of Gaspé, and the Macasty Shale of Anticosti Island.

*The C. spiniferus Zone.* The fauna of the 'true Utica' of Ruedemann as modified by Riva (1969), marks the beginning of the *C. spiniferus* Zone. This fauna contains great numbers of *O. quadrimucronatus micracanthus*, *O. amplexicaulis* in small numbers, *Cryptograptus insectiformis*, *C. caudatus*, and *Dicranograptus ramosus* (the last appearance for these two), as well as some new and diagnostic forms: *Climacograptus spiniferus*, *C. typicalis* (and its predecessor), *Orthoretiolites*, a new species of *Glyptograptus*, *Diplograptus* sp. (at the base), and *Dicranograptus* cf. *D. nicholsoni minor*. *Diplograptus ingens*, a form hitherto believed to be restricted to the Pacific faunal province, has been identified by the writer from the lower Utica of the Mohawk Valley. This fauna occurs in the lower half of the 'true Utica', part of the Macasty Shale of Anticosti Island, the flysch sequence of the St. Germain Complex, the Iberville Formation, part of the so-called Cloridorme 'Formation' of Gaspé, part of the Snake Hill Shale of Ruedemann, and the whole Snake Hill of Offield (1967), and its continuation in New Jersey, Pennsylvania, and Virginia (Ruedemann 1947, pp. 78-87; and unpublished collections in the New York State Museum).

*The C. pygmaeus Zone.* Changes in Utica faunas are gradual. Midway through the Utica *C. spiniferus* and *D. nicholsoni* cf. *minor* disappear and a small form of *C. typicalis*, *C. pygmaeus*, appears in profusion and ranges up to the top of the Utica. This change is also accompanied by the arrival of *Leptograptus flaccidus*, a new *Glyptograptus*, and a new *Orthoretiolites* with an extremely long virgella. *Corynoides* makes its last appearance here. *Orthograptus amplexicaulis* (possibly a subspecies), the typical *O. quadrimucronatus*, and a small member of the *quadrimucronatus* group known as *O. eucharis* (often in synrhabdosomes) appear in great numbers near the top of the Utica together with two new members of the *typicalis* group: *C. typicalis magnificus* and *C. typicalis posterus*. *Glyptograptus lorrainensis* is first seen here and passes into the succeeding zone. *Plenograptus linearis* has been recorded once from the upper Utica of the Mohawk Valley (Ruedemann 1908). In North America *P. linearis* is also known from the Phi Kappa Formation of Idaho (Churkin 1963, p. 1620) and the Point Leamington Greywacke, Fortune Peninsula, Newfoundland (J. Helwig 1967). Both collections are at Columbia University.

*The C. manitoulinensis Zone.* The typical elements of the Utica disappear with the cessation of the black shale sedimentation of the Utica: some members, however, persist into the grey siltstones and sandstones of the succeeding Lorraine Group. An impoverished fauna appears here with elements of the previous zone such as *C. pygmaeus*, *C. typicalis posterus*, *O. amplexicaulis* (a subspecies), *O. eucharis*, *O. quadrimucronatus*, *L. flaccidus*, and *Cryptograptus insectiformis*, all to disappear within the zone, *G. lorrainensis* which increases in size and continues on into the succeeding zones and some new elements such as *Pseudoclimacograptus* cf. *P. clevensis*, *Diplograptus* sp., *Climacograptus manitoulinensis*, *C. scalaris miserabilis*, a *Dicellograptus*, and rare dendroids. The arrival of the succeeding zone is heralded by the appearance of *Orthograptus abbreviatus*, *O. socialis*, and *Dicellograptus complanatus*.

This fauna is of restricted regional extent. Generally it is confined to the lower Lorraine Group of the St. Lawrence Lowlands of Quebec and Ontario and of the upper Mohawk Valley of New York; it also occurs in the upper Macasty Shale of Anticosti Island and Lake St. John and the lower part of the succeeding English Head Formation, or the lower Vauréal Formation of Bolton (1972). *P. cf. clevensis* is identical to *Climacograptus* cf. *extremus* reported by Ruedemann (1947, pl. 72, figs. 20-21) from the lower Whitehead Formation (Lespérance 1968, pp. 813-814) at Mont Joli, Percé, Quebec.

*Glyptograptus hudsoni* described by Jackson (1971) from Southampton Island in the North-West Territories and some collections from the same island and from Akpatok Island in Ungava Bay made by members of the Geological Survey of Canada and studied by this writer probably belong to the upper part of this zone. The Akpatok collections contained *Amplexograptus inuiti*.

*The D. complanatus Zone.* The characteristic graptolites of this zone are: *Dicellograptus complanatus*, as described by Skoglund (1963, pp. 33–36), and transients to *D. anceps*, *Orthograptus socialis*, *O. abbreviatus*, *C. scalaris miserabilis*, a large *Glyptograptus* descended from *G. lorrainensis*, a *Diplograptus*, and rare dendroids.

The zone is restricted to Anticosti Island and, possibly, the north-east part of the Gaspé peninsula. On Anticosti, it ranges through the upper English Head Formation (= lower Vauréal of Bolton 1972) to the base of the Vauréal Formation of Twenhofel. In Gaspé, Lespérance (1968) has reported graptolites in association with a *Remipyga* fauna of the Whitehead Formation. This writer has restudied these collections which contain *Climacograptus scalaris miserabilis*, *C. normalis*, *C. innotatus*, and a large *Glyptograptus* identical to that from Anticosti (identified as *D. (O.) rugosus* var. *apiculatus* on p. 815 of Lespérance's paper). This fauna is possibly correlative with the *D. complanatus* fauna of Anticosti, but little else can be said in the absence of more diagnostic elements.

*The Climacograptus prominens-elongatus Zone.* Most elements of the *D. complanatus* Zone disappear abruptly at the base of the Vauréal Formation of Twenhofel (or the upper Vauréal of Bolton) and in the succeeding 2000-foot interval to the top of the Ordovician, which includes the Vauréal and the Ellis Bay Formations, graptolites are rare. *Orthograptus abbreviatus*, the large *Glyptograptus* from the older zone, occur sparingly together with *Climacograptus prominens-elongatus* and rare dendroids. These formations contain an extensive shelly fauna, but may be regarded as practically devoid of graptolites.

The Late Ordovician graptolite succession of Anticosti resembles that of the Harjuan Series of Sweden (Jaanusson 1963, pp. 131–135; Skoglund 1963). In Scania the *D. complanatus* fauna occurs in a narrow zone of the *Tretaspis* beds (Jerrestad Stage) and it is succeeded by the *Dalmanitina* beds (Tommarp Stage) which are poorly graptoliteiferous. The middle and upper *Tretaspis* beds are correlated with the lower and middle Ashgill and the *Dalmanitina* beds with the upper Ashgill of Britain. The interval represented by the *C. prominens-elongatus* Zone may be interpreted to correspond to the *Dalmanitina* beds and the barren interval between the *D. anceps* and the *G. persculptus* Zone of the Moffat region in Scotland and the central zone of Wales (Lawson 1971). The stratigraphic succession on Anticosti certainly shows that a long interval there separates the top of the *D. complanatus* Zone from the base of the Silurian. Additional light on this problem is shed by a graptolite collection reported by Lespérance (1968, p. 816) from the *Dalmanitina* beds of the Whitehead Formation in Gaspé. The writer has restudied this collection and identified *Climacograptus rectangularis-medius* transients, and fragments of *Orthograptus*.

## SYSTEMATIC DESCRIPTION

Suborder DIPLOGRAPTINA Lapworth 1880, emend. Bulman, 1963

Family DIPLOGRAPTIDAE Lapworth, 1873

Genus CLIMACOGRAPTUS Hall, 1865

*Climacograptus bicornis* (Hall)

Plate 1, figs. 1–3, 5–7; text-figs. 1a–b

- 1847 *Graptolithus bicornis* Hall, pp. 268–269, pl. 73, figs. 2c–d?, 2f–h, 4 (non figs. 2a–b).  
 1865 *Climacograptus bicornis* (Hall); Hall, pp. 111–112, pl. A, figs. 13–17.  
 1908 *Climacograptus bicornis* (Hall); Ruedemann, pp. 80–85, pl. A, text-figs. 12–17; pp. 433–437, text-fig. 404 (non text-fig. 405), pl. 28, figs. 24, 25 (non fig. 26).  
 1947 *Climacograptus bicornis* (Hall); Ruedemann, p. 425, pl. 72, figs. 45, 46, 49–52 (non figs. 44, 47, 48).  
 1947 *Climacograptus bicornis* (Hall); Bulman, pp. 59–62, pl. 9, figs. 10–13.  
 1960 *Climacograptus bicornis* (Hall); Berry, p. 79, pl. 16, figs. 10, 11, pl. 19, fig. 4.  
 1963 *Climacograptus bicornis* (Hall); Ross and Berry, pp. 117–119, pl. 8, figs. 4–6, 9.  
 No attempt is made here to list synonymies from outside North America.

The original material of *Graptolithus bicornis* in the American Museum of Natural History consists of specimens of two distinct but superficially similar forms: *Climacograptus bicornis* (Hall) and *C. spiniferus* Ruedemann. Hall's (1847, pp. 268, 269) original description of *G. bicornis* broadly covered rhabdosomes with 'obtusate teeth', bearing 'two diverging forks at their base', which are 'sometimes thickened or expanded', as well as rhabdosomes characterized by 'mucronate' thecal apertures, or flanges covering the thecal excavations. The specimens with 'mucronate' apertures came from Cincinnati, Ohio, and were subsequently described by Hall (1865, pl. A, figs. 1-9) as *Climacograptus typicalis*. The originals of the forms now known as *C. bicornis* came from the classic graptolite locality in 'Hudson River beds' (now Austin Glen Greywacke) on the Normans Kill at Kenwood, south of Albany, N.Y., and those of *C. spiniferus* from the lower Utica Shale at Ballston Spa, N.Y. All these specimens were listed by Whitfield and Hovey (1898, p. 18) as part of the genotype of *Climacograptus* and 'species types' of *C. bicornis*. Specimens of *C. bicornis* constitute most of the originals of *G. bicornis*, but Hall's first figure of this species (1847, pl. 73, figs. 2a-b) was based on a *C. spiniferus*. This specimen bears a label with '*Graptolites bicornis*, Ballston Spa, Sar. Co.'

Apparently Hall did not recognize the difference in the type and origin of the 'diverging forks' or spines of the specimens before him when he erected *G. bicornis*. In *C. spiniferus* one spine grows out from the first thecae, th<sup>1</sup>, and the other is simply the down and outward extension of a well developed virgella or, perhaps, even the scicula; in *C. bicornis* a spine grows out from each of the first thecae, th<sup>1</sup> and th<sup>1</sup><sup>2</sup>. The presence or absence of a membrane on the basal spines is not in itself significant in differentiating between the two forms, for it will be seen further on that basal membranes or discs, though common to mature rhabdosomes of *C. bicornis*, occur also in *C. spiniferus*.

In erecting the genus *Climacograptus*, Hall (1865, pp. 111, 112, pl. A, figs. 13-17) refigured only original specimens from the graptolite locality on the Normans Kill as characteristic representatives of this genus, and these figures, well executed although somewhat stylized, were taken by subsequent workers as diagnostic of *C. bicornis*. Accordingly, the writer proposes as lectotype of *C. bicornis* and genolectotype of *Climacograptus* the first specimen (A.M.N.H. 1030a) figured by Hall (1865, pl. A, fig. 13) in erecting the genus *Climacograptus*. This specimen was part of the original collection of *G. bicornis* and was listed by Whitfield and Hovey (1898, p. 18) as part of the genotype specimens of *Climacograptus* and 'species types' of *C. bicornis*. [Whitfield was then a curator of the A.M.N.H. Prior to holding that position he had been for many years Hall's draughtsman and as such drew the 1865 figures of *C. bicornis*.] The specimen of Hall's first figure (1847, pl. 73, figs. 2a-b) of *G. bicornis* (A.M.N.H. 1041/5) is proposed here, instead, as the lectotype of *C. spiniferus*. It was on this specimen that Ruedemann (1908, pp. 411, 412), upon discovering the confusion in the original material of *G. bicornis*, founded mut. *spinifer* which later he (1912, p. 84) recognized as a distinct species and named *C. spiniferus*.

*Proposed Lectotype.* A.M.N.H. 1030a, from black shale in the lower part of the Austin Glen Greywacke, left bank of Normans Kill, just above an abandoned bridge at Kenwood, N.Y. For exact location, see the geologic map accompanying N.Y. State Museum Bull. 285, 1930.

*Other material.* A.M.N.H. 1034a, on slab bearing type of *Graptolithus mucronatus* (Hall 1847, pl. 73, fig. 1c); all figured material of *Graptolithus bicornis* catalogued as A.M.N.H. 1041/1, 1041/5; specimens from Hall's paratype collections in the American Museum of Natural History catalogued as 1036/5, and new collections from the type locality at Kenwood, N.Y. Most specimens are pyritized, and several are deformed or distorted to various degrees.

*Description.* The growth and morphology of the proximal end of this species have been described to some extent by Bulman (1947) on the basis of isolated Scottish material from the Laggan Burn section; the following discussion is concerned only with the type material and new specimens from the type locality and it is intended to accompany the selection of a lectotype and help differentiate this species from *C. spiniferus* Ruedemann, its descendant of the lower Utica Shale.

Rhabdosome long, attaining 10 cm and more in length, gradually widening from an initial width of 0.7-0.9 mm at the level of th<sup>1</sup>-1<sup>2</sup> to 1.8-2.3 mm, two cm from the proximal end, and to as much as 2.5-3.0 mm in distal parts of flattened individuals five cm or more in length. Thecae number 5-7 in the first 5 mm of the rhabdosome gradually increasing in size so as to number only 8-9 in 10 mm distally in mature individuals. Thecal excavations are wide and semicircular in immature rhabdosomes (Pl. 1, fig. 6; text-fig. 1a), tending to become narrower and shorter in mature individuals; apertures occupy from one-quarter to three-eighths the width of the rhabdosome and are surrounded by a well-developed selvage (Pl. 1, fig. 7; text-fig. 1). The geniculum



is sharply angular, the supragenicular wall generally parallel to the axis of the rhabdosome, the more so in flattened, mature individuals (Pl. 1, figs. 1, 7; text-fig. 1*b*) than in immature rhabdosomes (Pl. 1, fig. 6; text-fig. 1*a*). A conspicuous thecal spine grows out and downward from the first two thecae and may attain a considerable length in mature individuals (a little more than 5 mm in the lectotype) (text-fig. 1*b*). In mature rhabdosomes the spines may be enclosed in a membrane which may extend up to the proximal thecae. The rhabdosome is strongly septate. A thin virgula may extend distally for a short distance in some specimens (Pl. 1, fig. 7; text-fig. 1*a*).

The sicula is small, ranging from 0.72 to 1.3 mm in length (average for 11 siculae is 0.95 mm), and mostly exposed on the obverse side of the rhabdosome (text-fig. 1*a*). The virgella is short, being from 0.27 to 0.45 mm in length (the most common length is 0.36 mm) and pointing toward the theca<sup>2</sup> series. Theca 1<sup>1</sup> originates high on the sicula, grows down toward the sicular aperture, then curves outward and gently upwards until the aperture faces outwards, almost parallel with the side of the rhabdosome (text-fig. 1*a*). The apertural excavation is shallow. Theca 1<sup>2</sup> grows farther upwards than th 1<sup>1</sup> and its aperture is set deeper into the rhabdosome, facing more distally than ventrally (Pl. 1, fig. 6; text-fig. 1*a*). The succeeding thecae all grow upwards, overlapping each other by one-third. The septum begins at the th 2<sup>1</sup>-2<sup>2</sup> level near the base of th 3<sup>1</sup> and continues on to the end of the rhabdosome, leaving a deep septal furrow.

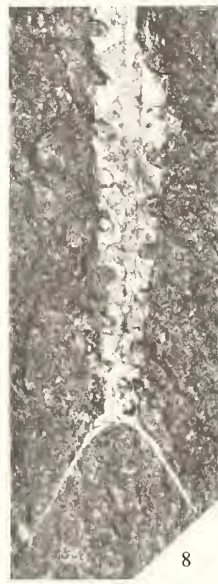
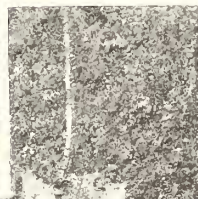
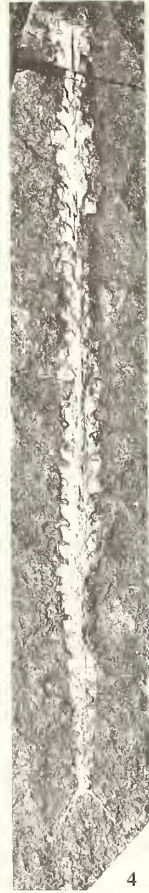
The thecal spines are given off at the lower corners of the rhabdosome. The spine of th 1<sup>1</sup> is flush with the aperture, but that of th 1<sup>2</sup> grows slightly below the aperture (Pl. 1, fig. 6; text-fig. 1*a*). A study presently being carried out on several hundred topotypes indicates that these spines grow constantly through the formation of the rhabdosome, being short, thin, and wiry in immature rhabdosomes with less than five pairs of thecae (length less 1 mm, width 0.07 mm and less) and long and thick in

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EXPLANATION OF PLATE 1

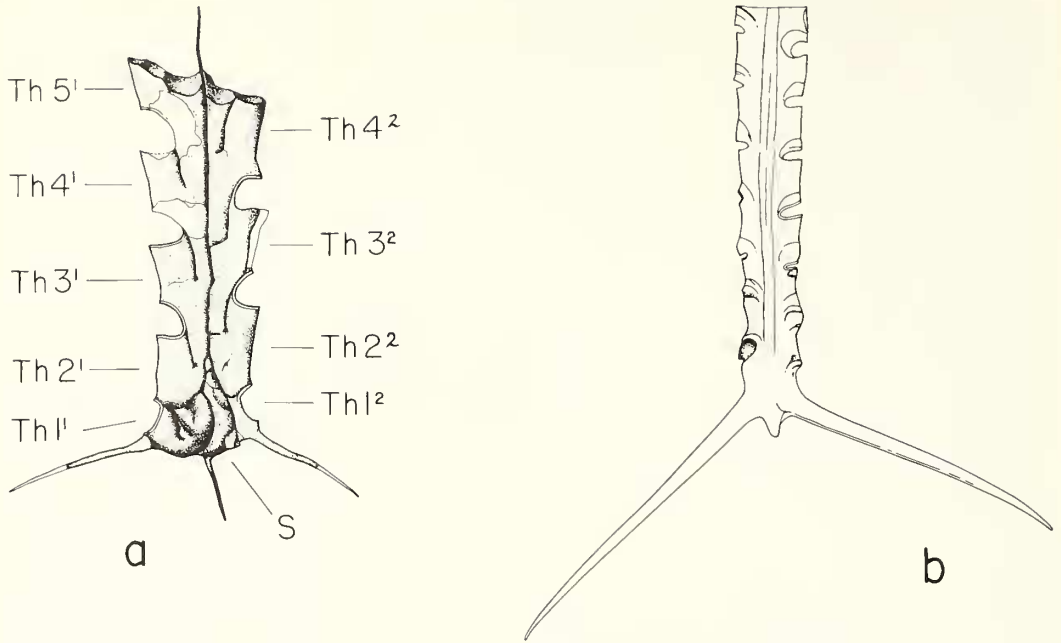
Figs. 1-3, 5-7. *Climacograptus bicornis* (Hall). 1. Proposed lectotype, A.M.N.H. 1030a, figured by Hall (1865, pl. A, fig. 13). Only the external mould now remains, although the rhabdosome was still preserved in 1962. Obverse view of mature specimen, distally broken.  $\times 5$ . 2, 3. Paratype, A.M.N.H. 1036/5a not previously figured. Mature rhabdosome with well-developed proximal spines, thickened virgella, and showing partly deformed supragenicular walls of proximal thecae. This specimen was recently recovered from the A.M.N.H. general collections. Its counterpart, A.M.N.H. 1041/1b, labelled 'type' of *C. bicornis*, is not figured because of poor and fragmentary preservation.  $\times 5$  and  $\times 2$ . 5. Paratype, on slab bearing a type of *Graptolithus mucronatus* (Hall), A.M.N.H. 1034a. Reverse view showing basal spines free of membranes, slightly thickened virgella, and square thecal outlines.  $\times 6$ . 6. Paratype, A.M.N.H. 1041c, not previously figured. Reverse view of immature rhabdosome showing characteristically thin basal spines, thin virgella, round thecal apertures surrounded by strong selvage, and virgula prolonged distally. Thecal apertures of th 1<sup>1</sup> and 1<sup>2</sup> are clearly visible.  $\times 10$ . 7. Paratype, A.M.N.H. 1031/1a, not previously figured. Mature rhabdosome in obverse view, with strongly developed basal spines and virgella free of membrane, narrow thecal aperture enclosed by a strong selvage. Aperture of th 1<sup>1</sup> visible.  $\times 4$ .

Figs. 4, 8. *Climacograptus spiniferus* Ruedemann. Proposed lectotype, A.M.N.H. 1041/5a, and Hall's (1847, pl. 73, figs. 2*a-b*) first figure of *Graptolithus bicornis*. 4, complete specimen,  $\times 3-12$ . 8, proximal end with thin and symmetrically arranged proximal spines, and with a tiny membrane covering the virgellar spine.  $\times 8$ . The specimens of *C. bicornis* are from the Austin Glen Greywacke on the Normans Kill at Kenwood, N.Y. The lectotype of *C. spiniferus* is from the lower Utica Shale at Ballston Spa, N.Y.



RIVA, *Climacograptus* spp.





TEXT-FIG. 1. Proximal end of *Climacograptus bicornis* (Hall) from Austin Glen Greywacke at Kenwood, N.Y. *a*, Topotype. Immature rhabdosome in moderate relief, obverse side showing exposed sicula, virgella, mode of growth of th 1<sup>1</sup> and th 1<sup>2</sup>, position of their apertures and point of growth of thecal spines, and point of origin of septum;  $\times 19$ . *b*, Proximal end of lectotype, A.M.N.H. 1030a, showing size of proximal spine, virgella enclosed by membrane, and deformed apertures of proximal thecae. Obverse view. Drawn from actual specimen in 1962;  $\times 8$ .

mature rhabdosomes (length 5 mm and more, width 0.4 mm at the point of origin) (compare text-figs. 1*a* and 1*b*). No 'basal membranes' were noted on immature rhabdosomes with less than 15 pairs of thecae. A slight bulge, however, begins to form on top or around each spine in individuals with 16 pairs of thecae and more. This bulge may remain small and insignificant or grow out to both ends of the spines, surrounding the virgella, and in some cases, extend up on the proximal end of the rhabdosome as far as the sixth pair of thecae, blocking off thecal apertures (as seen in profile at least). Specimens with 'basal membranes' or discs have been separated as var. *peltifer* by Lapworth (1876) and others with apparently even more peculiar membranes as var. *signum* by Ruedemann (1908), but more realistically they should be regarded as mature rhabdosomes of *C. bicornis* which have developed basal membranes, the function of which is purely speculative. Var. *signum* does not seem to be characterized by distinct membranes: a review of its type material suggests that the peculiarities illustrated by Ruedemann (1908, pl. A, facing p. 82) are due to torn membranes, failure to remove matrix around the basal discs, deformation, and preservation. Not all mature rhabdosomes of *C. bicornis* bear basal membranes. The lectotype (Pl. 1, fig. 1; text-fig. 1*b*) has only a tiny membrane around the virgella, and the other mature specimens from the Hall collections illustrated on Plate 1 (figs. 2, 3, 5, 7) bear none. Specimens devoid of basal membranes are figured in this



paper in preference to others only in order to be able to show clearly the differences between *C. bicornis* and *C. spiniferus*.

A few immature individuals of the toptype collection now under study bear a long virgella (more than 1.00 mm long) longer than the basal spines. Rhabdosomes with long virgellas have been separated as var. *tridentatus* by Lapworth (1876), and this may well be a valid designation at the subspecific level because a long virgella is already present in immature individuals. Basal membranes may enclose both the basal spines and the long virgella of subspecies *tridentatus* or may be reduced or entirely absent. There are all variations between the two extremes.

*Remarks.* The lectotype and one other mature specimen in the Hall collections (Pl. 1, figs. 1, 2, 3) present a deformed proximal end: the apertures of the first two or three pairs of thecae are closed off by what appears to be the collapse of the infragenicular wall of the next succeeding theca, the supragenicular wall having become misshapen in the process. In the lectotype the aperture of th 1<sup>1</sup> is also entirely obscured by what could be secondary deposits. The rhabdosome of Plate 1, figs. 2, 3, bears a short virgella also conspicuously thickened by secondary deposits.

A study of Ruedemann's collections has revealed an interesting detail: the rhabdosome repeatedly figured by Ruedemann (1908, text-fig. 405, pl. 28, fig. 26; 1947, pl. 72, figs. 44, 47, 48) as a typical *C. bicornis* but with weak proximal spines and 'peculiar, deeply notched' thecal apertures is in reality an *Amplexograptus*. Individuals belonging to this genus have been collected by this writer at the Normans Kill locality.

The only species close to *C. bicornis* is *C. spiniferus* which is essentially a slightly modified descendant of *C. bicornis* in which th 1<sup>1</sup> has grown down and upwards making a full U-turn, and th 1<sup>2</sup> has grown outwards and upwards, losing its thecal spine. A spine in this position, however, is formed by the virgella growing down and outwards as a spine, symmetrical to that of th 1<sup>1</sup> (text-fig. 2a-h). In all other details the proximal ends of *C. bicornis* and *C. spiniferus* are similar, including the sicula fully exposed on the obverse side of the rhabdosome and the origin of the septal groove in the th 2<sup>1</sup>-2<sup>2</sup> region.

*Stratigraphic and geographic occurrence.* *C. bicornis* is a cosmopolitan species ranging through the *N. gracilis* and *D. multidentis* Zones or their equivalents. In north-eastern North America it is restricted to units of the Appalachian sequences, such as the Mount Merino Chert and Shale, the Austin Glen Greywacke, the Quebec City Formation, the Beauceville slates, the Stanbridge slates, part of the 'Cloridorme Formation' of Gaspé, the Walloomsac Formation, the Indian River Shale and Chert, and to blocks of wildflysch accumulation derived from the Appalachian sequences.

### *Climacograptus spiniferus* Ruedemann

Plate 1, figs. 4, 8; text-figs. 2, 3, 4

- 1847 *Graptolithus bicornis* Hall, pp. 268-269, pl. 73, figs. 2a-b (non 2c-s).  
 1908 *Climacograptus typicalis* mut. *spinifer* Ruedemann, pp. 411-412, text-figs. 236, pl. 28, figs. 8-9.  
 1912 *Climacograptus spiniferus* Ruedemann, p. 84.  
 1947 *Climacograptus spiniferus* Ruedemann, p. 439, pl. 73, figs. 1-7.  
 1955 *Climacograptus spiniferus* Ruedemann; Clark and Strachan, pp. 692-693, text-figs. 3d, f.  
 1963 *Climacograptus spiniferus* Ruedemann; Ross and Berry, p. 130, pl. 9, fig. 12.  
 1969 *Climacograptus spiniferus* Ruedemann; Riva, p. 521, text-figs. 3k-p.  
 1971 *Climacograptus spiniferus* Ruedemann; Berry, p. 637, pl. 73, fig. 5.

*Proposed Lectotype.* A.M.N.H. 1041/5, bearing label with '*Graptolites bicornis*, Ballston Spa, Sar. Co' (Pl. 1, figs. 4, 8; text-figs. 4a, b). The specimen most likely came from an outcrop of basal Utica Shale on the left bank of an unnamed tributary of Kayaderoseras Creek in the southern part of Ballston Spa, N.Y. The outcrop is located just west of the 'Old Iron Spring'.

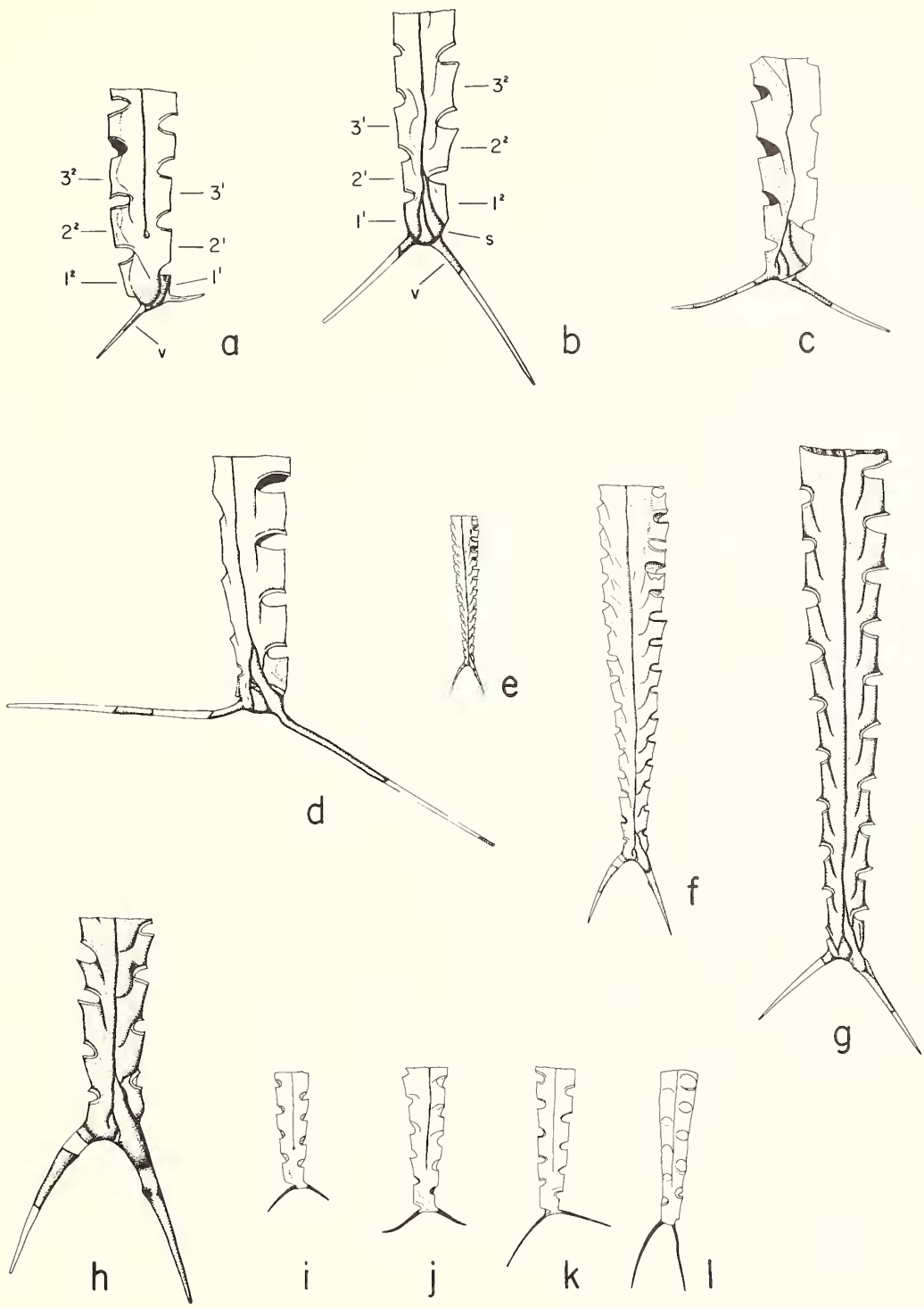
*Material and localities.* Topotype specimens from Ballston Spa, N.Y., in the collections of the P. Redpath, Museum, McGill University, Montreal (these specimens were presented to the University by James Hall at the opening of the Museum in 1882). Extensive collections from the lower Utica Shale, zone of *C. spiniferus*, in New York and Quebec, the Macasty Shale of Anticosti, the Cloridorme Formation of Gaspé, the parautochthonous flysch of Quebec, and the Schenectady beds of New York. Canadian specimens figured in this paper are deposited in the type collections of the Geological Survey of Canada, numbered G.S.C. 31710 to 31729.

*Description.* Rhabdosome long, attaining as much as 7 cm and more in length (excluding proximal spines), widening gradually from 0.70–0.85 mm at the aperture of th 1<sup>2</sup> to 2 mm, 1 to 2 cm from the proximal end, and to 2.2–2.8 mm maximum observed in flat, mature individuals (text-figs. 4g, i). Thecae number 10–30 (average 11–12) in the first 10 mm of the rhabdosome, decreasing to 9–11 distally in individuals 4 cm and more in length. The apertural excavations are moderately deep and wide, about one-quarter to one-third the width of the rhabdosome and one-quarter to one-third the length of the free ventral of the thecae; they are generally semicircular in immature rhabdosomes, more adpressed in mature rhabdosomes, always strengthened by a well-developed selvage merging the apertural margin with the infragenicular wall. The supragenicular wall may be parallel or slightly inclined away from the axis of the rhabdosome. The proximal end characteristically bears a pair of spines, one of which is the thecal spine grown outwards from th 1<sup>1</sup> and the other the virgella grown down and outwards, often symmetrically with the thecal spine. A membrane may enclose the proximal spines and exceptionally the virgella may bifurcate. The rhabdosome is septate.

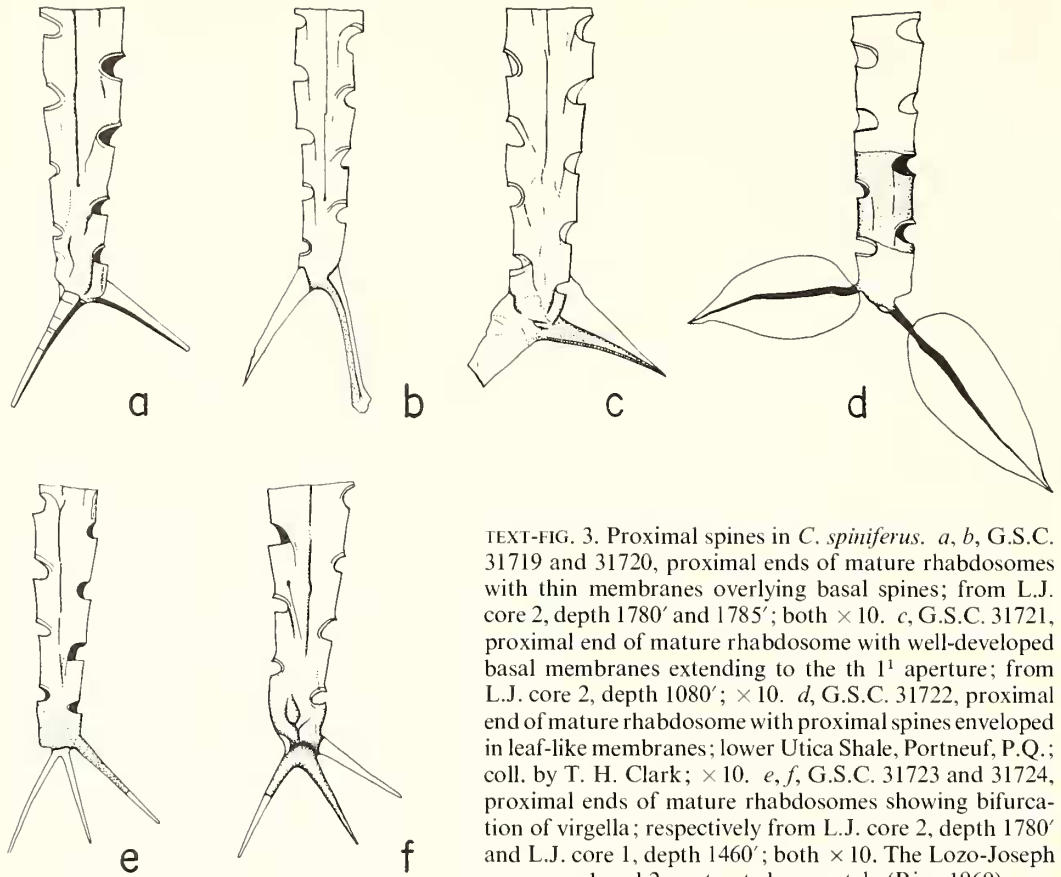
The development of the early stages of *C. spiniferus* does not differ essentially from that of *C. diplacanthus* Bulman (1932, pp. 13–16). The sicula is almost fully exposed on the obverse side of the rhabdosome and tilted toward the th<sup>2</sup> series (text-figs. 2b–h). The septum originates in the th 2<sup>2</sup>–2<sup>1</sup> region and continues on to the distal end, leaving a deep septal groove (text-figs. 2a, b, d, g, j).

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TEXT-FIG. 2. Proximal spines in *C. spiniferus*. a, Reverse view of immature rhabdosome, G.S.C. 31710, with thin, short, and asymmetrical basal spines; septal groove originates in th 2<sup>1</sup>–2<sup>2</sup> region; from L.J. 2 core, depth 1800'; × 10. b, Obverse view of proximal end of mature rhabdosome, G.S.C. 31711, showing tilted, exposed sicula, symmetrical basal spines but of unequal length, and mode of growth of th 1<sup>1</sup>; from L.J. 2 core, depth 1680'; × 10. c, G.S.C. 31712, obverse view, with nearly symmetrical spines, and showing exposed sicula and mode of growth of th 1<sup>1</sup>; from L.J. 2 core, depth 1040'–1045'; × 10. d, Proximal end of mature rhabdosome, G.S.C. 31713, obverse side, with exceptionally developed but asymmetrical basal spines; from basal Utica Shale at Neuville, P.Q.; × 10. e, f, h, Broad rhabdosome, obverse view, G.S.C. 31714, with exceptionally thickened virgellar spine symmetrical to that of th 1<sup>1</sup>; from lower Utica Shale at Neuville, P.Q.; respectively × 2, × 5, × 10. g, Rhabdosome in low relief, obverse view, G.S.C. 31730, showing thickened virgellar spine symmetrical to that of th 1<sup>1</sup>; from lower Utica Shale, Neuville, P.Q.; × 10. i, j, Flattened immature rhabdosomes, G.S.C. 31715, 31716, with minute proximal spines of nearly equal length; respectively from L.J. core 1, depth 1295' and L.J. core 2, depth 985'–990'; both × 5. k, l, Proximal ends of mature rhabdosomes, G.S.C. 31717, 31718, in obverse and subscalariform views; from L.J. core 2, depth 1770' and 1780'; both × 5. The Lozo-Joseph cores 1 and 2 are treated separately (Riva 1969).





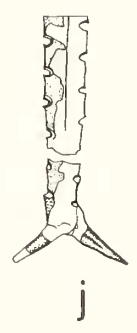
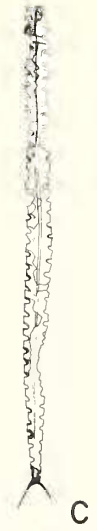
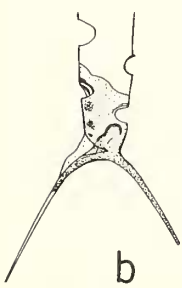
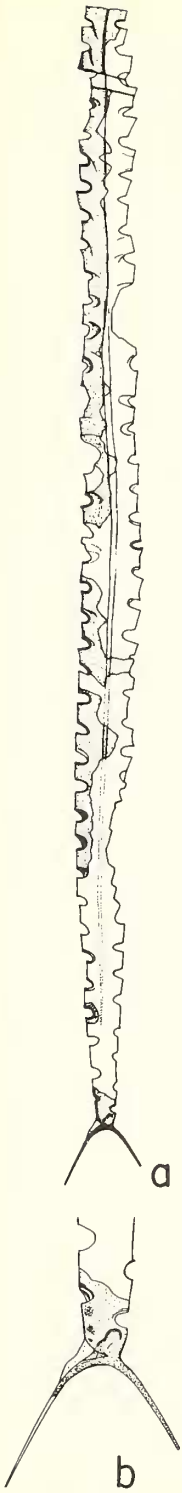


TEXT-FIG. 3. Proximal spines in *C. spiniferus*. *a, b*, G.S.C. 31719 and 31720, proximal ends of mature rhabdosomes with thin membranes overlying basal spines; from L.J. core 2, depth 1780' and 1785'; both  $\times 10$ . *c*, G.S.C. 31721, proximal end of mature rhabdosome with well-developed basal membranes extending to the th  $1^1$  aperture; from L.J. core 2, depth 1080';  $\times 10$ . *d*, G.S.C. 31722, proximal end of mature rhabdosome with proximal spines enveloped in leaf-like membranes; lower Utica Shale, Portneuf, P.Q.; coll. by T. H. Clark;  $\times 10$ . *e, f*, G.S.C. 31723 and 31724, proximal ends of mature rhabdosomes showing bifurcation of virgella; respectively from L.J. core 2, depth 1780' and L.J. core 1, depth 1460'; both  $\times 10$ . The Lozo-Joseph cores 1 and 2 are treated separately (Riva 1969).

TEXT-FIG. 4. *Climacograptus spiniferus* Ruedemann. *a-c*, Proposed lectotype, A.M.N.H. 1041/5 from basal Utica at Ballston Spa, N.Y., and Hall's (1847, pl. 73, figs. 2a-b) first figure of *Graptolithus bicornis*. *a*, Full rhabdosome showing the thin, symmetrically arranged proximal spines;  $\times 4.6$ ; *b*, detailed view of proximal end showing origin of proximal spines and the virgella covered by a residual membrane;  $\times 10$ ; *c*, the same;  $\times 2$ .

*d-j*, From the Lower Utica of Neuville, Quebec.

*d*, Reverse view of rhabdosome, G.S.C. 31725, twisted distally to an oblique view;  $\times 3$ . *e*, Typical oblique view of rhabdosome, G.S.C. 31726, with thickened virgella;  $\times 5$ . *f*, Reverse view of rhabdosome, G.S.C. 31727, showing septal groove originating in the th  $2^1-2^2$  region, and thin, symmetrically arranged proximal spines;  $\times 5$ . *g-h*, Obverse view of large rhabdosome, G.S.C. 31728. *g*, full rhabdosome with distal part drawn from slab counterpart;  $\times 3$ . *h*, detailed view of proximal end showing short, thickened proximal spines;  $\times 8$ . *i-j*, Mature rhabdosome, G.S.C. 31729, in biprofile view proximally, and twisted to an oblique view distally. *i*, complete rhabdosome;  $\times 2$ . *j*, detailed view of proximal end showing short, stubby proximal spines thickened up to the aperture of th  $1^1$ ;  $\times 5$ .



Considerable variation characterizes the proximal end of *C. spiniferus* particularly in the development of the proximal spines. (The following comments do not constitute a study of the astogenetic growth of the species, but are the result of observing extensive collections from various localities and cores from north-eastern North America). Spines of immature individuals with five pairs of thecae or less (text-figs. 2*a, i, j*) are tiny and thin, the thecal spine measuring as little as 0.5 mm in length and the virgella, or virgellar spine, 1.00 to 1.3 mm. Spines may be asymmetrically or, less commonly, nearly symmetrically arranged around the proximal end, with the virgella directed more downwards than the thecal spine (text-figs. 2-4). The virgella is usually slightly to markedly longer than the thecal spine. Both spines develop to various degrees during the growth of the rhabdosome: some spines, like those of the lectotype (Pl. 1, figs. 4, 8; text-figs. 4*a-c*) grow long but remain very thin, a few others (text-fig. 3*d*) grow to exceptional lengths (maximum observed is 3.7 mm); most spines, however, are shorter, from 1.5 to 2.5 mm in length, and tend to thicken. In some mature specimens, thickening of the spines has proceeded to such an extent that the sicula itself appears to have been prolonged as a spine (text-figs. 2*e, f, g, h*; 4*e, g-j*). Thickened spines tend to grow more symmetrically than thin spines. Finally, basal membranes may lie on, or enclose, one or both spines (text-figs. 3*a-d*). These membranes may be just barely developed or have grown upwards so as to cover the aperture of th 1<sup>1</sup> (text-figs. 3*a, c*), as in *C. bicornis*. Few individuals of *C. spiniferus*, however, bear basal spines and these occur more commonly in collections from the lower Utica Shale, which corresponds to the lower range of the species. Exceptionally the virgella may bifurcate, furnishing the proximal end with three basal spines (text-figs. 3*e, f*).

*Remarks.* *C. spiniferus* is practically identical to *C. diplacanthus* described by Bulman (1932) from collections from the Wesenberg Beds of Kurland, Estonia. The only difference between these two species is that thecal excavations are shallower in *C. diplacanthus* than in *C. spiniferus*, occupying one-seventh the breadth of the rhabdosome in the former versus one-quarter or less in the latter. Mature rhabdosomes of *C. diplacanthus* with thickened proximal spines (Bulman 1932, pl. 3, figs. 1, 4-5) cannot be distinguished from similar rhabdosomes of *C. spiniferus* (text-figs. 4*g-j*). It might be better to regard *C. diplacanthus* as a subspecies of *C. spiniferus* or a geographic variant of the same.

*C. spiniferus* could be considered a descendant of *C. bicornis*, which has undergone some definite modifications in the proximal end. The sicula is largely exposed on the obverse side of the rhabdosome as in *C. bicornis*, but th 1<sup>1</sup> has grown both down and upwards making a full U-turn, rather than only down and outwards in an inverted C, as in *C. bicornis*. Th 1<sup>2</sup> grows farther upwards, but has lost its thecal spine which is replaced by the virgella grown outwards as a second spine (compare text-fig. 1*a* with text-figs. 2*a-d*). Spines are generally shorter in *C. spiniferus* and basal membranes have either disappeared or are reduced considerably in size. The septum originates at the th 2<sup>1-2</sup> level as in *C. bicornis*; thecal spacing is similar in the two species.

*Stratigraphic and geographic occurrence.* *C. spiniferus* occurs widely in north-eastern North America ranging in great numbers through the zone bearing its name (Riva 1969). It is common in the lower Utica Shale, the Schenectady beds, part of the Snake Hill Shale of New York, parts of the parautochthonous sequence of Quebec (St. Germain Complex), the 'Cloridorme Formation' of Gaspé, the Macasty Shale of Anticosti Island, and their stratigraphic equivalents. The writer has also identified it from Unit C of the



Summerford Group of north-central Newfoundland (Horne 1970, pp. 1772-1773) and other units from Notre Dame Bay. This species also occurs in the Viola Limestone of Oklahoma (Ruedemann and Decker 1934), the lower Maravillas Chert of Texas (Berry 1960), and from the western United States and Canada (Ross and Berry 1963; Riva 1970, p. 2712; Jackson *et al.* 1964). I. Strachan (written comm., 1963, 1973) has recognized it at Girvan and Moffat in Scotland.

*C. diplacanthus* has been reported from Sinkiang, China (Mu *et al.* 1960), besides Estonia.

Near the top of the Utica there occurs a short, broad climacograptid with short basal spines, less than 1 mm long, one of which is the virgella and the other a spine on the 1<sup>st</sup> (Riva 1969, figs. 4*m, n*). The poor material hitherto on hand has prevented a description of this form which, however, can only be interpreted as a descendant of *C. spiniferus* characterized by extremely reduced or atrophied basal spines.

### *Climacograptus putillus* (Hall)

1865 *Graptolithus putillus* Hall, pp. 27, 44, pl. A, figs. 10-12*a*.

1908 *Climacograptus putillus* (Hall); Ruedemann, pp. 415-419 (*partim*), text-figs. 368-370 (*non* text-figs. 371-377).

1925 *Climacograptus putillus* (Hall); Ruedemann, pp. 60-64 (*partim*).

1947 *Climacograptus putillus* (Hall); Ruedemann, pp. 434-435, pl. 72, figs. 29, 32, 33, 30?, 31?, 34-42?

Ruedemann (1925, pp. 60-64) attempted to separate the minute Middle Ordovician graptolites that he (1908) and other workers had previously referred to *C. putillus* and distinguished six forms among them: *Climacograptus eximius*, *C. strictus*, *C. tenuis*, *C. pygmaeus*, *C. lorrainensis*, and *C. putillus s.s.* A restudy of the type material of these species and the study of other collections from type localities and equivalent strata in New York and Quebec have led the writer to suggest some additional modifications and revisions:

1. *Climacograptus lorrainensis*. This form belongs to *Glyptograptus* and it is identical with *C. rougensis* Parks from the upper Utica (Gloucester) of Ontario (Riva 1969, p. 526, figs. 6*d-f*; Parks 1928, pp. 63-64, text-figs. 6-8). *G. lorrainensis* ranges through the upper Utica and the lower Lorraine.

2. *Climacograptus pygmaeus* and *C. tenuis*. These two names refer to the same species. Ruedemann described rhabdosomes of a *Climacograptus*, 6-8 mm long and 0.7-0.8 mm wide, from the upper Utica Shale at Mohawk, N.Y., as *C. pygmaeus*, and identical forms, but 12 mm long and 1 mm wide, from the base of the upper Utica at the Trenton-Utica contact on Big Brook near Westernville, N.Y., as *C. tenuis*. The study of numerous individuals from the upper Utica has amply demonstrated that this form commonly attains 1 mm in width and may, exceptionally, be as much as 15-17 mm long, although shorter individuals (6-8 mm) predominate.

Both names were proposed by Ruedemann (1925, p. 63) at the same time but accompanied only by descriptions. However, the 1925 description of *C. pygmaeus* contains a reference to previously figured specimens (Ruedemann 1908, p. 416, text-fig. 376) which he (1947, pl. 72, figs. 22-24) subsequently designated as cotypes (= syntypes) of *C. pygmaeus*. On the other hand, no figures of *C. tenuis* were ever published by Ruedemann, although a search through the N.Y. State Museum revealed a specimen (N.Y.S.M. 11542) from near Westernville, N.Y., that he had selected as type but never figured. Accordingly, the name *C. pygmaeus* stands in preference, according to article 28a of the International Rules over *C. tenuis* and agrees with the name usually given to these tiny climacograptids.

3. *Climacograptus eximius*. Here Ruedemann (1925, pp. 62, 64) raised to specific

rank deformed, minute climacograptids which he had previously (1908, p. 420, text-figs. 378-384) separated as *C. putillus* mut. *eximius*. The type material of *eximius* contains two distinct forms: the specimens of the first three 1908 figures (text-figs. 378, 379, and 380?) belong to *Pseudoclimacograptus modestus* (Ruedemann) and the other four (text-figs. 381-384) to *C. brevis strictus* as redefined below. Ruedemann apparently referred to *eximius* all minute climacograptids from Normanskill beds near Albany, N.Y. In raising mut. *eximius* to specific rank, Ruedemann (1925, p. 62) noted that *C. eximius* was characterized by 'distinctly climacograptid . . . thecae'. This qualification best applies to the specimens of the first three 1908 figures of mut. *eximius*, rather than to the other four which have more smoothly rounded, almost sigmoidal thecae. The name *C. eximius* thus becomes a junior synonym of *P. modestus*. It is discussed further below.

4. *Climacograptus strictus*. The name *C. strictus* was intended for climacograptids with less closely spaced thecae than those referred to *C. eximius* and separated by 'wide notches'. It was believed to be restricted to the lower Canajoharie Shale. Identical specimens from Normanskill beds were included in *C. eximius*. Morphologically the types of *C. strictus* are similar to those of *C. brevis* Elles and Wood, but differ from the latter in being invariably smaller, both shorter and narrower, suggesting a clearly distinct subspecies of *C. brevis*. It will be treated as such below.

5. *Climacograptus putillus* (Hall). Hall's (1865, pl. A, figs. 10-12a) type is an internal mould of a climacograptid in full relief, from the Maquoketa Shale near Dubuque, Iowa. Ruedemann (1908, p. 416, text-figs. 369, 370) figured the type in full, together with a proximal fragment on the same slab, but added nothing else to the knowledge of the morphology of the species. Paratype material in the A.M.N.H. collected by Hall from a locality 12 miles west of Dubuque, Iowa, contain some flattened material with the periderm partly preserved which suggests *Climacograptus crassitestus* (Ruedemann). Other paratype material from Iowa and Illinois labelled *D. putillus* consists, instead, of internal moulds of *Diplograptus peosta* (Hall) (= *Orthograptus amplexicaulis*), also in full relief.

#### *Climacograptus brevis strictus* (Ruedemann)

Plate 2, figs. 1-3; text-figs. 5a-j

- 1908 *Climacograptus putillus* (Hall) (*partim*); Ruedemann, pp. 415-419, text-figs. 371-373 (*non* figs. 368-370, 374-377), pl. 28, figs. 14, 15, 16a.  
 1908 *Climacograptus putillus* (Hall) mut. *eximius* Ruedemann (*partim*), pp. 420, text-figs. 381-384 (*non* figs. 378-380), pl. 28, fig. 16.  
 1925 *Climacograptus strictus* Ruedemann, pp. 62, 63.  
 1947 *Climacograptus strictus* Ruedemann, p. 436, pl. 72, figs. 16-19.  
 1947 *Climacograptus eximius* Ruedemann (*partim*), pl. 72, figs. 4-7, 13?

*Holotype*. N.Y.S.M. 6953 (Ruedemann 1947, pl. 72, fig. 17) from Snake Hill Shale in a quarry (now partly filled) located on the right side of stream flowing through the Albany Rural Cemetery (Section 23). The quarry is about 400 feet north of the tomb of U.S. President Arthur.

*Other material*. N.Y.S.M. 6950, 6951, 6952, all designated as cotypes (= paratypes) of *C. strictus*, from the same locality as the holotype. N.Y.S.M. 6914, 6915, 6917, from Normanskill shale at station 30 (Ruedemann 1901, pp. 541-542), north end of Lansingburg, N.Y.; and N.Y.S.M. 6916, from Normanskill shale at station 34 (op. cit., p. 543), Glenmont, N.Y. (The last four specimens are listed as cotypes of *C. eximius* by Kilfoyle, 1954, pp. 77-78.) A.M.N.H. 1042 on slab bearing holotype (part) of *C. parvus*, lower Austin

Glen Greywacke at Kenwood, N.Y.; A.M.N.H. 1042A, 1042B, Hall's collections. An individual on the same slab as the holotype, N.Y.S.M. 6953.

*Description.* Rhabdosome short, attaining a maximum known length of 13 mm but commonly less than 10 mm (virgella and nema excluded), and narrow, widening from 0.7–0.8 mm at the level of the 1<sup>2</sup> aperture to 0.9–1.1 mm (average 1 mm) distally. Thecae are six to seven in the first 5 mm of the rhabdosome. Apertural excavations are deep, about one-third the width of the rhabdosome, and long, half the length of the free ventral wall of the thecae. Apertural excavations are commonly semicircular, rounded on the inside and strengthened by a thin selvage. The supragenicular wall tends to be inclined away from the axis of the rhabdosome; the geniculum is usually rounded off or smooth, thus giving a sigmoidal appearance to thecae of individuals preserved in subscalariform view. The proximal end is characteristically provided with a thin virgella about 0.4–0.5 mm long; the sicula is about 0.8 mm long. A thin virgula extends through and beyond the rhabdosome.

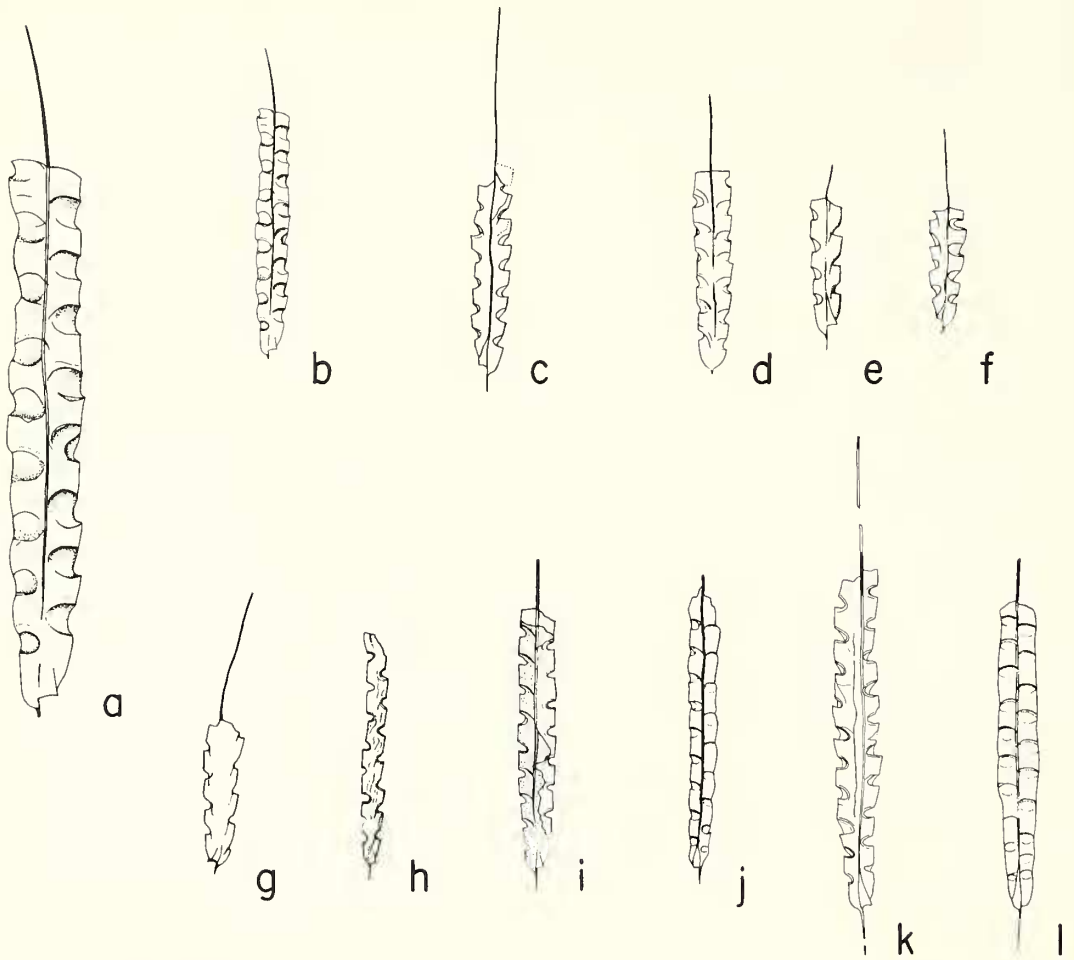
*Discussion.* Specimens of *C. brevis strictus* are commonly preserved in subscalariform view which, when flattened, give the rhabdosome the nondescript appearances of text-figs. 5a, b, d, j and of Plate 2, fig. 3. The holotype itself (text-figs. 5a, b) is preserved similarly. No trace of a septum or septal groove has been seen on the type specimens, but it will likely show up on better material.

In erecting *C. eximius* and *C. strictus*, Ruedemann (1925, p. 64) surmised that the former was closely related to *Glyptograptus teretiusculus* var. *siccatus* and the latter indistinguishable from *Climacograptus brevis*, both as figured and described by Elles and Wood (1906–1907). He indicated, however, that only 'actual comparison could settle the question of their relationships'. The writer has studied the type and topotype material of Elles and Wood's species and subspecies and has noted that: (1) *G. teretiusculus* var. *siccatus* is based on rhabdosomes of *C. brevis* compressed diagonally so that thecal outlines appear sigmoidal; and (2) much of the type material of var. *siccatus* and *C. brevis* is from the same locality and horizon near Builth, Wales. Strachan (1971, p. 39) considers var. *siccatus* synonymous with *C. brevis*.

*C. brevis* is morphologically identical with *C. strictus*, but rhabdosomes of *C. brevis* are invariably larger—being commonly 9 mm long, up to 1.2 mm wide, and with sicula 1 mm and virgella 1.0–1.2 mm long—than those of *C. strictus* (compare text-figs. 5a–j with text-figs. 5k–l) and, consequently, *C. strictus* is here considered a distinct subspecies of *C. brevis*.

*C. brevis strictus* could be compared to *C. pauperatus* Bulman from the Middle Ordovician of Scandinavia, but the latter differs in being both shorter and narrower although it has a comparable thecal spacing. Strachan's (1959) *C. brevis mutabilis* from Sweden is close to *C. brevis strictus* in length and thecae spacing, but the former is much broader and differs in details of the proximal end.

*Geographic and stratigraphic occurrence.* In eastern North America *C. brevis strictus* ranges through the *N. gracilis*, *D. multidentis*, and the *C. americanus* Zones. It is of infrequent occurrence in Normanskill strata but it becomes more common in Magog and lower Canajoharie beds. In the Canajoharie, *C. brevis strictus* gradually increases in size to the much larger *C. mohawkensis* (= *C. minimus* of Elles and Wood) which is dominant in the upper Canajoharie. No form of the *brevis-mohawkensis* group occurs in the Utica and younger rocks of north-eastern North America, but a form of this group, *C. crassitestus* (Ruedemann), persisted into the Upper Ordovician of the Ouachita Geosyncline.



TEXT-FIG. 5. *Climacograptus brevis strictus* (a-j) and *C. brevis* (k, l). a, b, Holotype, N.Y.S.M. 6953, obliquely compressed. From Snake Hill Shale, Albany Rural Cemetery, Albany, N.Y.; respectively  $\times 10$  and  $\times 5$ . c, e, f, Cotypes, N.Y.S.M. 6952, from group figured by Ruedemann (1908, pl. 28, fig. 14) as *C. putillus*. From Snake Hill Shale, Albany Rural Cemetery, Albany, N.Y.; all  $\times 5$ . d, Specimen on same slab as the holotype, N.Y.S.M. 6953, opposite side; obliquely compressed;  $\times 5$ . g, N.Y.S.M. 6916, figured by Ruedemann (1908, p. 240, fig. 383) as mut. *eximius*. From Mt. Merino Chert and Shale at Glenmont, N.Y.;  $\times 5$ . h, N.Y.S.M. 6914, figured by Ruedemann (1908, p. 420, fig. 381) as mut. *eximius*. The counterpart was also figured by Ruedemann (op. cit., fig. 384). The specimen is badly deformed by lateral compression. From Mt. Merino Chert and Shale at Lansingburg, N.Y.;  $\times 5$ . i, j, Rhabdosomes on A.M.N.H. 1042. i, biprofile view, periderm partly lost, flat; j, oblique view, laterally compressed. From the lower Austin Glen Greywacke on the Normans Kill at Kenwood, N.Y.; both  $\times 5$ . k, l, Topotypes of *C. brevis strictus* for comparison with *C. brevis strictus*. k, rhabdosome in biprofile view (least common), BU 1849; l, rhabdosome in oblique view (most common), BU 1850. Lapworth collection at Birmingham University, England. From Llandrindod Wells, Wales; both  $\times 5$ .



*Climacograptus pygmaeus* Ruedemann

Plate 2, figs. 6, 11; text-figs. 6a-h, 7a-h

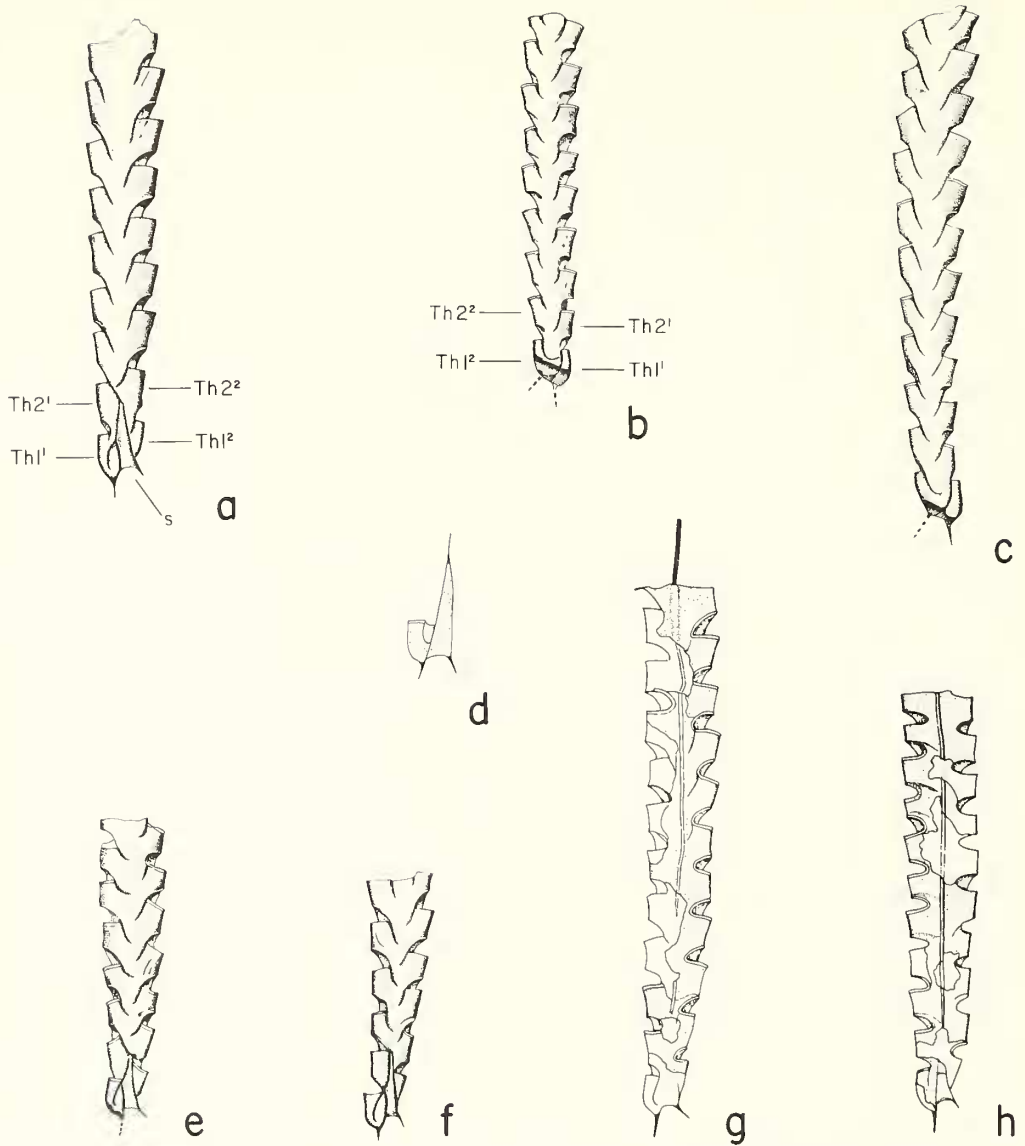
- 1908 *Climacograptus putillus* Hall; Ruedemann, pp. 415-419 (*passim*), fig. 376.  
 1925 *Climacograptus pygmaeus* Ruedemann, p. 63.  
 1925 *Climacograptus tenuis* Ruedemann, p. 63.  
 1928 *Climacograptus prolificus* Parks, pp. 61-62, fig. 5.  
 1947 *Climacograptus pygmaeus* Ruedemann, pp. 435-436, pl. 72, figs. 22-24.  
 1947 *Climacograptus tenuis* Ruedemann, p. 436, pl. 75, figs. 12?-15?  
 1947 *Climacograptus prolificus* Parks; Ruedemann, pp. 436-437, pl. 74, fig. 58 (*non* fig. 59).  
 1969 *Climacograptus pygmaeus* Ruedemann; Riva, p. 522, figs. 4f-h.  
 1970a *Climacograptus pygmaeus* Ruedemann; Berry, p. 272, text-fig. 1b.

*Syntypes*. N.Y.S.M. 6942. The syntypes consisted of three tiny rhabdosomes (Ruedemann 1908, p. 416, fig. 376) which, because of the fragile nature of the periderm, have flaked off. It will be, perhaps, necessary to select a neotype from the upper Utica Shale at the type locality which is on Fuller Creek, near Mohawk, N.Y.

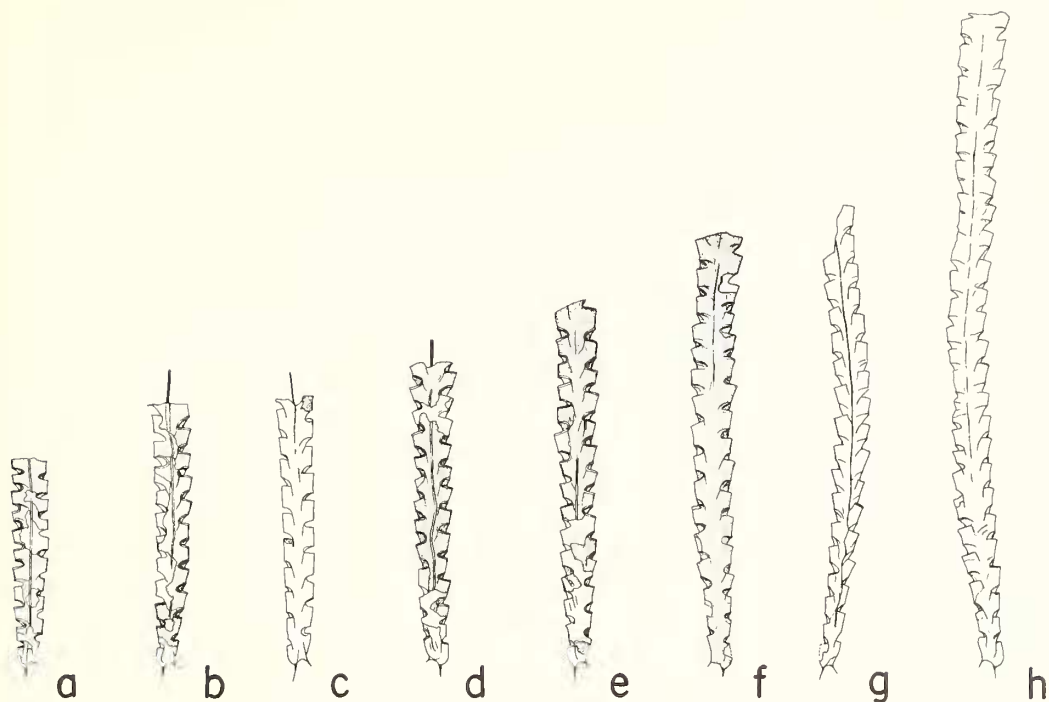
*Other material*. N.Y.S.M. 11542, proposed type of *C. tenuis*, from the uppermost Utica on Big Brook, east of Westernville, N.Y.; R.O.M. 264 bearing types of *C. prolificus*, from the upper Collingwood Shale (= upper Utica) at Camperdown, Ontario; several pyritized rhabdosomes, in full or low relief, from the upper Utica of the Lozo-Joseph 1 and 2 cores, the Bald Mountain core of the St. Lawrence Lowlands of Quebec (Riva 1969). Extensive collections of flattened specimens from the aforementioned cores and other localities in the upper Utica Shale of the St. Lawrence Lowlands.

*Description*. Rhabdosome small, commonly 6-8 mm long but frequently attaining 10-12 mm and, exceptionally up to 17 mm in length, and thin, widening imperceptibly from 0.5-0.6 mm at the level of th 1<sup>2</sup> to 0.8-1.2 mm (average 0.9-1.0 mm) between the fifth and the seventh pair of thecae. Thecae are small and closely spaced, usually 7-8.5 (average 8) in the first 5 mm of the rhabdosome (excluding the first pair of thecae), decreasing distally to about 14-15 in 10 mm in exceptionally long rhabdosomes. Thecae are square, tending to be inclined away from the axis of the rhabdosome in specimens preserved in relief (text-fig. 6c) or as flattened films (text-figs. 7d-h); they overlap one-third the succeeding thecae. Apertural excavations are usually wide, deep, and semicircular, occupying at least one-third the width of the rhabdosome. The proximal end bears a short, spiny virgella about 0.2-0.5 mm long and thickened by secondary material from the rhabdosome and two sicular spines. The sicula is 1.2-1.3 mm long (text-fig. 6d). The virgula extends through and for a short distance beyond the rhabdosome. The rhabdosome is aseptate. The sicular is mostly exposed on the obverse side of the rhabdosome as far as the aperture of th 2<sup>1</sup> (text-figs. 6a, e, f). Th 1<sup>1</sup> grows first down from the middle part of the sicula to well below the sicular aperture and then it grows sharply upwards until its aperture reaches or passes the point of origin on the sicula (text-figs. 6a, e, f); th 1<sup>2</sup> first grows across the rhabdosome behind the sicula, and then turns upwards terminating well above the aperture of th 1<sup>1</sup> (text-figs. 6b, c). The periderm of *C. pygmaeus* is thin and brittle, flaking off readily even in fresh specimens. Rhabdosomes in relief are rare, but when so preserved they are oval, rectangular, or semicircular in cross-section (Pl. 2, figs. 6, 11; text-figs. 6a-c).

*Remarks*. *C. pygmaeus* is a dwarfed member of *C. typicalis* group which found its optimum development in the black Utica Shale of north-eastern North America.



TEXT-FIG. 6. *Climacograptus pygmaeus* Ruedemann. *a*, Rhabdosome in full relief, G.S.C. 31731, obverse side, showing sicula exposed up to the level of  $th\ 2^1-2^2$ , wide apertural excavations, absence of thecal hoods and type of spines at the proximal end. From Bald Mountain core, depth 1715';  $\times 10$ . *b*, *c*, Rhabdosomes in full relief, G.S.C. 31732-31733, reverse side, showing wide apertural excavations and gently, inclined thecae. From Lozo-Joseph 2 core, depth 325'-330'; both  $\times 10$ . *d*, Flattened sicula of *C. pygmaeus* with  $th\ 1^1$  fully developed. From Lozo-Joseph 2 core, depth 190'-195';  $\times 10$ . *e*, *f*, Rhabdosomes in low relief, G.S.C. 31734-31735, obverse views, showing sicula exposed up to the aperture of  $th\ 1^2$  and  $2^1$  respectively, and wide apertural notches. From Lozo-Joseph 1 core; depth 655'; both  $\times 10$ . *g*, *h*, Flattened rhabdosomes, G.S.C. 31736-31737, obverse views, showing typical preservation of average size specimens with periderm partly flaked off, apertural excavations enclosed by a thin selvage, and virgula showing beneath periderm. From Lozo-Joseph 2 core, depth 155'-160' and 285'-289' respectively; both  $\times 10$ .



TEXT-FIG. 7. Variation in the length of *Climacograptus pygmaeus* Ruedemann. *a, b*, Average size rhabdosomes, G.S.C. 31736-31737, flattened, with periderm partly lost. Same as those of text-figs. 6*g-h*;  $\times 5$ . *c*, Average size rhabdosome, G.S.C. 26584, with periderm gone except for tiny fragments, parallel-sided, and showing typically square thecal outlines. From Bald Mountain core, depth 1565';  $\times 5$ . *d, e*, Longer and slightly wider rhabdosomes, G.S.C. 26585-26586, than preceding ones with markedly inclined thecae, periderm largely preserved, and virgula partly visible under periderm. From Lozo-Joseph 1 core, depth 660'; both  $\times 5$ . *f*, Long and wide rhabdosome, G.S.C. 26587. Periderm is largely preserved but thecal details are largely obscured. From Bald Mountain core, depth 1885';  $\times 5$ . *g, h*, Exceptionally long and bent rhabdosomes, G.S.C. 26588-26589; from a level in the Bald Mountain core (1925' and 1945', respectively) characterized by long individuals of *C. pygmaeus*; both  $\times 5$ .

All these specimens are deposited in the collections of the Geological Survey of Canada. The cores referred to are discussed elsewhere (Riva 1969).

A study of the development of the *typicalis* group through more than 2000 feet of Utica shows that *C. typicalis* first appears about 400 feet above the base of the true Utica, as redefined (Riva 1969, p. 514), and ranges up to the top of the formation. *C. pygmaeus* appears suddenly and in great numbers in the middle of the Utica. This is the first form to branch off *C. typicalis*, to be followed near the top of the Utica by *C. typicalis magnificus*, a giant biserial form with a 4.0-4.5 mm width and a narrow, whip-like proximal end, and by forms intermediate between *C. typicalis* and *C. pygmaeus* which are presently referred to as *C. typicalis posterus*. (The principal members of the *typicalis* group are figured in Riva 1969, p. 527, figs. 4*a-j, o*.)

*C. pygmaeus* differs from *C. typicalis* by its minute size, tightly packed thecae, the imperceptible widening of the rhabdosome and the absence of a hood over the thecal apertures. It is closer to the rhabdosomes referred to as *C. typicalis posterus*

particularly in the gradual widening of the rhabdosome and the absence of thecal hoods, but it differs in being smaller and narrower and having much more closely packed thecae.

*Geographic and stratigraphic occurrence.* *C. pygmaeus* is restricted to the upper Utica Shale and equivalent strata of north-eastern North America where it ranges through a zone bearing its name. Usually it is present in great profusion, literally covering and blackening whole bedding surfaces. In New York it ranges through the upper Utica Shale and the Atwater Creek, Deer River and the basal Frankfort shales and sandstones of the upper Mohawk and Black River Valley; in the Champlain Valley and the St. Lawrence it also ranges through the upper Utica into lower Lorraine strata; in Ontario it is recorded, both as *C. pygmaeus* and as *C. prolificus*, in the Collingwood Formation (uppermost Utica) (Parks 1928; Caley 1936). Farther westwards it has been recognized as far as the northern Michigan Peninsula in shales correlative with the uppermost Utica (Ruedemann and Ehlers 1924; Berry 1970a). This writer has identified it in a collection from the Cincinnati area in Ohio (Albers coll. in the A.M.N.H.). *C. pygmaeus* also occurs in great numbers in the Macasty Shale of the Lake St. John area, deep in the Precambrian Shield, and of Anticosti Island (Riva 1969). This form has not been reported from the Appalachian sequences, except for a few individuals tentatively referred to it by this writer from the Hillgrade Shale of the Notre Dame Bay, Newfoundland (coll. by Marshall Kay 1970). In the Hillgrade collections, *C. cf. pygmaeus* is associated with a typical British *P. linearis* fauna which includes *P. linearis* itself, the third known occurrence of this species in North America.

Genus PSEUDOCLIMACOGRAPTUS Přibyl, 1947  
*Pseudoclimacograptus modestus* (Ruedemann)

Text-figs. 8a, b

- 1908 *Climacograptus putillus* mut. *eximius* Ruedemann (*partim*), p. 420, text-figs. 378, 379, 380? (*non* text-figs. 381–384, pl. 28, fig. 16).  
 1908 *Climacograptus modestus* Ruedemann, pp. 432–433, text-figs. 400–403, pl. 28, fig. 30.  
 1925 *Climacograptus eximius* Ruedemann; Ruedemann (*partim*), pp. 62, 64.  
 1947 *Climacograptus modestus* Ruedemann; Ruedemann, p. 432, pl. 73, figs. 32–46.  
 1947 *Climacograptus eximius* Ruedemann; Ruedemann (*partim*), p. 435, pl. 72, figs. 2, 3 (*non* figs. 1, 4–15).  
 1948 *Climacograptus modestus* Ruedemann; Bulman, pp. 222–223, text-fig. 1.

*Material studied.* N.Y.S.M. 6911, 6912, 6913, from Mt. Merino Chert and Shale blocks at station 30 (Ruedemann 1901, pp. 541–542) at the north end of Lansingburg, N.Y.

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TEXT-FIG. 8. *Pseudoclimacograptus* spp. *a, b*, Syntypes of *C. eximius*, herein referred to *P. modestus* (Ruedemann). *a*, N.Y.S.M. 6912, deformed and fragmental rhabdosome showing deep apertural excavations; *b*, N.Y.S.M. 6913, laterally compressed, but showing spinose nature of proximal end. From Mt. Merino Chert and Shale at Lansingburg, N.Y.; both  $\times 5$ . *c, d, e, f*, *P. scharenbergi*. *c*, rhabdosome on A.M.N.H. 1042D, one of a group of eight short individuals labelled *C. parvus*; *d*, rhabdosome on A.M.N.H. 1034, with type of *G. mucronatus*, showing zigzag septal groove, long virgella accompanied by sicular downgrowth; *e*, rhabdosome on A.M.N.H. 1030a with lectotype of *C. bicornis*, clearly showing zigzag septum, long virgella, and sicular downgrowth; *f*, long rhabdosome on A.M.N.H. 1040C. This specimen is labelled *C. parvus* and is next to a specimen figured by Hall (1847, pl. 73, fig. 4g) as *Graptolithus scalaris*, but which is really a *C. parvus* compressed in scalariform view; other specimens on the same slab are also of *C. parvus*. From the Austin Glen Greywacke on the Normans Kill at Kenwood, near Albany, N.Y.; all  $\times 5$ . *g, h*, Type of *C. parvus*, A.M.N.H. 1042A, not previously figured. This specimen bears a label with 'n.sp.' From Austin Glen Greywacke on the Normans Kill at Kenwood, N.Y.; respectively  $\times 5$  and  $\times 3$ . *i*, *P. scharenbergi steuostoma*, A.M.N.H. 1034/1a, on reverse side of slab bearing a syntype of *Graptolithus mucronatus* (Hall 1847, pl. 73, fig. 1c), showing slit-like thecal excavations and trace of zigzag septum at level of th 2<sup>1</sup>. From Austin Glen Greywacke on the Normans Kill at Kenwood, N.Y.;  $\times 5$ .





a



b



c



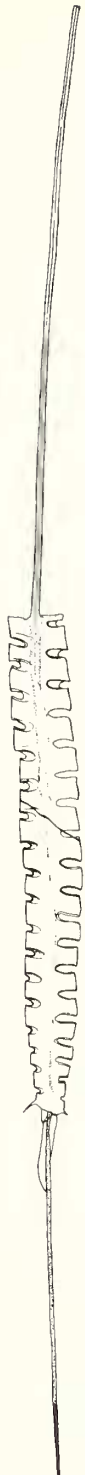
d



e



f



g



h



i

*Remarks.* The morphology of *Pseudoclimacograptus modestus* has been adequately described by Ruedemann (1908) and Bulman (1948). The types of *P. modestus* came from Normanskill Chert and Shale of a quarry at the north end of Mt. Merino, N.Y. (Ruedemann 1908, pp. 13–15, 423). In erecting this species Ruedemann (1908, p. 423) noted that the form also occurred in collections from 'the same horizon at the northern end of Lansingburg', to the north of Troy, N.Y. The Lansingburg collections contain also a number of small climacograptids which Ruedemann (1908, p. 420) first distinguished as mut. *eximius*, and later (1925, p. 62) clearly separated as *C. eximius*.

As already pointed out in the discussion under *C. putillus*, Ruedemann assigned two forms to mut. *eximius*: the individuals of his 1908 text-figs. 378, 379, and possibly 380 are deformed or fragmental *P. modestus*, while those of text-figs. 381–384 are identical to *C. brevis strictus* as redefined in this paper. The rhabdosome of text-fig. 378 (herein refigured as text-fig. 8*b*) is distorted or compressed normally to its axis, as shown by the narrow width (0.7 mm versus 1 mm in undeformed specimens), unequal though deep thecal apertures, and, especially, by the straight rather than convex supragenicular walls. The rhabdosome typically bears three proximal spines (the virgella, and mesial spines on th 1<sup>1</sup> and th 1<sup>2</sup>), has eight thecae in its first 5 mm, and shows traces of a zigzag septal groove. The rhabdosome of text-fig. 379 (herein refigured as text-fig. 8*a*) is fragmental as well as deformed, but enough is left to show that its width barely exceeds 1 mm, thecae are nine in 5 mm, thecal excavations are deep and narrow, and supragenicular walls are distinctly convex. A faint trace of a zigzag septal groove can be seen in the middle of the rhabdosome. The proximal part is missing, but in all other respects this specimen is identical to *P. modestus*. The rhabdosome of text-fig. 380 is too deformed to be adequately understood.

*Pseudoclimacograptus scharenbergi stenostoma* (Bulman)

Text-fig. 8*i*

- 1947 *Climacograptus scharenbergi* var. *stenostoma* Bulman, p. 70, pl. 7, figs. 11, 12, pl. 8, figs. 2–4, 8.  
 1960 *Climacograptus scharenbergi* var. *stenostoma* Bulman; Berry, p. 83, pl. 15, fig. 6.

*Material.* Specimen on A.M.N.H. 1034/1a bearing a type of *Hallograptus mucronatus* (Hall 1847, pl. 73, fig. 1c); Austin Glen Greywacke, Kenwood, N.Y.

*Remarks.* Bulman (1947, p. 70) distinguished as var. *stenostoma* a form similar in many respects to *P. scharenbergi* but differing in being narrower and having 'exceedingly narrow, slit-like' thecal excavations. In North America this variety has since been reported from the Normanskill of New York (Berry, 1962*a*), from the Woods Hollow Shale of Texas (Berry 1960), and the Valmy Formation of Nevada (Ross and Berry 1963). This writer has found it, but sparingly, in several Normanskill collections from the Appalachians. It is also likely that some tiny climacograptids referred to, or identified, as *Climacograptus eximius*, *C. putillus*, or *Pseudoclimacograptus modestus* may more properly belong to subsp. *stenostoma*.

No American specimen of subspecies *stenostoma* has yet been figured, except for an individual from the Woods Hollow Shale tentatively identified as such (Berry 1960, pl. 15, fig. 6). The specimen here figured (Pl. 2, fig. 10; text-fig. 8*i*) is on a slab of the Hall collection in the A.M.N.H. The rhabdosome is mostly preserved, in slight relief, 5.3 mm long (proximal spines excluded), 0.9–1.0 mm wide, and with eight to

nine thecae in the first 5 mm of the rhabdosome. Thecal excavations are characteristically narrow, slit-like, and deep and strengthened by a thin selvage merging the infragenicular wall with the thecal aperture. The excavations of the first three thecae are slightly wider than those of the more distal thecae. The proximal end is furnished with three spines: the virgella and a mesial spine on each of the first two thecae. The supragenicular walls are markedly convex and thecal apertures slightly introverted. A trace of the zigzag septal groove can be seen in the th  $1^2$ - $2^1$  region, but this feature is scarcely visible even in the holotype, which is an 'isolated' rhabdosome.

The subspecies *stenostoma* approaches *P. modestus* particularly in the width of rhabdosome, number of thecae per 5 mm and over-all appearance. Distinction between these two forms may, in fact, be difficult with flattened specimens. Subspecies *stenostoma* differs from *P. modestus*, as from *P. scharenbergi*, principally in its characteristically slit-like apertural excavations, and in the more convex supragenicular walls. These features alone should be sufficient criteria to separate at least relatively undeformed specimens.

*Pseudochimacograptus scharenbergi* (Lapworth)

Plate 2, figs. 4, 5; text-figs. 8c-h

- 1865 *Climacograptus parvus* Hall, p. 57 (*nom. nudum*).
- 1876 *Climacograptus Scharenbergi* Lapworth, pl. 2, fig. 55.
- 1896 *Climacograptus phyllophorus* Gurley, pp. 77-78, pl. 4, figs. 4-6.
- 1906 *Climacograptus Scharenbergi* Lapworth; Elles and Wood, p. 206, text-fig. 116, pl. 27, figs. 14a-e.
- 1908 *Climacograptus scharenbergi* Lapworth; Ruedemann, pp. 428-431, text-figs. 394-399, pl. 28, fig. 31.
- 1908 *Climacograptus parvus* Hall; Ruedemann, pp. 90-96, 426-428, text-figs. 20, 24-26, 27, 28, 33-36, 388-393, pl. 28, figs. 19-23.
- 1932 *Climacograptus scharenbergi* Lapworth; Bulman, pp. 6-10, text-figs. 1-3, pl. I, figs. 1-35.
- 1947 *Climacograptus scharenbergi* Lapworth; Bulman, pp. 65-70, text-figs. 34-38, pl. 7, figs. 1-10, pl. 8, figs. 1, 5-7.
- 1947 *Climacograptus scharenbergi* Lapworth; Ruedemann, pp. 438-439, pl. 74, figs. 41-54.
- 1947 *Climacograptus parvus* Hall; Ruedemann, p. 433, pl. 74, figs. 10-26.
- 1960 *Climacograptus parvus* Hall; Berry, p. 81, pl. 16, fig. 12.
- 1963 *Climacograptus scharenbergi* Lapworth; Ross and Berry, p. 129, pl. 9, figs. 14, 17.
- 1963 *Climacograptus phyllophorus* Gurley; Ross and Berry, p. 127, pl. 8, fig. 17?, pl. 9, figs. 13?, 18?

For a more complete record on the distribution of *P. scharenbergi*, see Strachan 1971, p. 44.

*Material examined.* Type of *Climacograptus parvus* Hall, part and counterpart, A.M.N.H. 1042A and B; eight small rhabdosomes and one fragment on the type slabs; a large rhabdosome on the type slabs next to specimen illustrated by Hall (1847, pl. 73, fig. 4g) as *Graptolithus scalaris*; a rhabdosome on A.M.N.H. 1034/1a bearing type of *Graptolithus mucronatus* (Hall 1847, pl. 73, fig. 1a); a rhabdosome on A.M.N.H. 1030a bearing the lectotype of *C. bicornis*.

*Remarks.* The morphology and general features and abnormalities of young and mature rhabdosomes of this species have been fully described and illustrated by Bulman (1932, 1947). The following discussion is concerned rather with the type of *C. parvus* (or *C. phyllophorus*) and other material in the A.M.N.H.

The name *C. parvus* has had a somewhat tortuous history. It was first proposed by Hall in 1865 but remained a *nomen nudum* until Gurley in 1896 renamed and described the specimen in question as *C. phyllophorus*. Ruedemann, however, on the

grounds that Hall's name was long established and recognized before Gurley's, revived *C. parvus* in 1908 and the name persisted unchallenged in the American literature until 1963 when Ross and Berry called Ruedemann's action 'ill-advised' and reinstated *C. phyllophorus*. Much of this confusion stems from the failure to study critically the morphology of the type specimen of *C. parvus* and the associated topotype material, and the tendency to attribute to *C. parvus* characteristics which also belong to *P. scharenbergi*. The type specimen itself (Pl. 2, fig. 5; text-figs. 8g, h) has never been figured. Ruedemann's (1908, text-fig. 388; 1947, pl. 74, text-fig. 10) figure of *C. parvus* is from the impression on the counterpart of the type slab (Pl. 2, fig. 4) and it is rather stylized with most of the critical features not shown. The specimen itself is 13 mm long (excluding virgella and virgula) and widens gradually from 0.8 to 1.5–1.6 mm. Thecae are thirteen to fourteen in 10 mm proximally (excluding the first pair), with supragenicular walls appearing straight rather than convex because the rhabdosome is compressed obliquely. Apertural excavations are narrow and deep occupying at least one-third the width of the rhabdosome and strengthened by a thin selvage. The proximal end bears a spine on the first two thecae and an extremely long virgella (9.5 mm). The initial portion of the virgella is partly enclosed in a 2-mm long downgrowth which is interpreted as a sicular downgrowth similar to those recognized by Bulman (1947, pp. 68–69, text-fig. 36) in Laggan Burn specimens of *P. scharenbergi*. The virgula is long (17 mm), thick (0.2 mm), and formed by two parallel bands; it carries no 'disc' or vane at the distal end. Because the rhabdosome is flattened, no trace of a septum can be recognized, but otherwise the type of *C. parvus* shows the characteristic features of *P. scharenbergi*.

Several rhabdosomes on the type slab of *C. parvus* and in the rest of the Hall collection from the Normans Kill bear an original Hall label with '*C. parvus*'. Of these, eight small ones and a large one are on the type slabs: one of the small ones, shown here as text-fig. 8c, clearly shows the deep and narrow thecal excavations, the convex supragenicular walls, the width, a trace of zigzag septum, and the beginning of a sicular downgrowth along the virgella as in *P. scharenbergi*; identical features are also seen on the larger rhabdosome (text-fig. 8f), except for the sicular downgrowth. The trace of the zigzag septum is best shown by two other specimens of the Hall collection (text-figs. 8d, e); these also exhibit a long virgella accompanied by a sicular downgrowth. None of these specimens carry a trace of a 'disc', or vane, at the end of the virgula. It is obvious that in 1865 Hall named but did not describe as *C. parvus* specimens which were later named and described as *C. scharenbergi* by Lapworth (1876).

Gurley (1896, p. 77) based *C. phyllophorus* on the type of *C. parvus*. He considered, as Ruedemann did later (1947, p. 434) for *C. parvus*, the 'disc' at the end of the virgula as the characteristic feature of this form. A 'disc', however, is absent on the types of *C. parvus*, and Bulman (1964, pp. 462–463) has shown that such feature is typical of *P. scharenbergi*.

Ruedemann considerably expanded the concept of *C. parvus* as shown by his 1908 figures (p. 426) repeated in 1947. Besides the type and one other form with sicular downgrowths (p. 426, text-figs. 388–389), he figured specimens with long and narrow apertural excavations and a 'vesicle' at the end of a long virgula (Pl. 28, figs. 19–23; text-fig. 391), as well as a specimen with more shallow thecal excavations, but pro-



vided with a virgella and mesial spines on th 1<sup>1</sup> and 1<sup>2</sup>. He noted in the discussion of *P. scharenbergi* (p. 431) that *C. parvus* differs from *P. scharenbergi* in the absence of a zigzag septal groove and in having shallow rather than deep apertural excavations. But the types of *C. parvus* have deep apertural excavations and the zigzag septal groove cannot be recognized because the specimen is compressed. Ruedemann, in fact, shows on p. 430, text-figs. 394–399, that the zigzag septal groove of *P. scharenbergi* disappears with increasing deformation.

*Geographic and stratigraphic occurrence.* *P. scharenbergi* is a common species in Middle Ordovician rocks of north-eastern North America, where it ranges through both the *N. gracilis* and the *D. multidentis* Zones. Individuals bearing a long virgella and an accompanying sicular downgrowth were found to be common in recent collections from the Quebec City Formation, which is almost entirely in the *D. multidentis* Zone. In this part of North America no *Pseudoclimacograptus* has ever been recognized above the *D. multidentis* Zone, i.e., from the *C. americanus* to the beginning of the *C. manitoulinensis* Zone, an interval comprising more than 3000 feet of undisturbed black Canajoharie and Utica shales. A new *Pseudoclimacograptus*, *P. cf. P. clevensis* Skoglund (Riva 1969, p. 526, figs. 6j, k), appears in the *C. manitoulinensis* Zone associated with a graptolite fauna similar to that reported by Skoglund (1963) from the lower Harjuan Series of Sweden.

### Genus ORTHOGRAPTUS Lapworth, 1873 *Orthograptus amplexicaulis* (Hall)

Plate 2, figs. 7–10; text-fig. 9

- 1847 *Graptolites amplexicaule* Hall, pp. 79–80, 316, pl. 26, figs. 11a–b.  
 1867 *Diplograptus amplexicaule* (Hall); Hall, pp. 24, 223, pl. 3, figs. 6, 7.  
 1908 *Diplograptus* (*Glyptograptus*) *amplexicaulis* (Hall); Ruedemann, pp. 361–365, text-figs. 302–304, 305–306?, 307, pl. 25, figs. 11, 13, 10?, 12?  
 1947 *Diplograptus* (*Amplexograptus*) *amplexicaulis* Hall; Ruedemann (*partim*), pp. 411–412, pl. 70, figs. 1–4, 7–9, 5–6?, 10–13? (*non* fig. 14).  
 1960 *Orthograptus truncatus* var. *intermedius* Elles and Wood; Berry, p. 92, pl. 17, figs. 4–5.  
 1960 *Orthograptus* aff. *O. truncatus* (Lapworth); Berry, pp. 91–92.  
 1969 *Orthograptus amplexicaulis* (Hall); Riva, fig. 3a.

This synonymy is restricted to specimens from the type locality or equivalent strata.

*Proposed lectotype.* A.M.N.H. 634/1, Trenton Limestone at Middleville, N.Y. (Pl. 2, fig. 6). The type locality could be any of the following exposures, and part of the same horizon: (1) Moltentanner Creek, one mile east and above Middleville; (2) City Brook, two miles north-east of the city; (3) Stony Brook, two miles south of the city. The lectotype is the specimen figured by Hall in 1867, pl. 25, figs. 6–7. It is one of the two specimens listed by Whitfield and Hovey (1898, p. 20) as the ‘types’ of the species.

*Material and localities.* All type material in the A.M.N.H. labelled 643/1 from Middleville, N.Y., including a recently discovered collection (still in the original bag) made by Hall in 1847 from the Trenton Limestone at Trenton Falls, N.Y. (and bearing a label with: ‘*G. amplexicaule* Hall, Trenton Falls, very rare, I have just got two of them’). The J. W. Hall collection in the N.Y. State Museum from the Trenton Limestone at Middleville, N.Y. catalogued as 7128 (Harris quarry), 7129 (Stony Brook), 7130 (Moltentanner Creek). All specimens from the Trenton Limestone are preserved in low to full relief. The writer has had at his disposition extensive collections from the Canajoharie Shale at Chuctenunda Creek, the Snake Hill Shale of the Hudson River Valley, and the Utica Shale of New York, and from Trenton (Cobourg) Limestone, Canajoharie–Utica and Lorraine shales and siltstones of the St. Lawrence Lowlands, and the Macasty Shale of Anticosti Island. Ruedemann’s collections in the N.Y. State Museum, those of Parks in the Royal Ontario Museum, and those of Twenhofel from Anticosti Island in the Yale Peabody Museum have also been examined. The writer has also studied most of the specimens of *Orthograptus truncatus* (Lapworth) figured by Elles and Wood (1907, pp. 233–235, pl. 29, figs. 3a, b, e) in the Lapworth collection of Birmingham University and additional material from the Hartfell Shales in the Sedgwick Museum at Cambridge University.

*Description.* The following description is based on the type material and also flattened rhabdosomes from Canajoharie–Utica Shales. No attempt is made to define the upper stratigraphic limit of the species as such a conclusion will have to be based on much larger and varied collections.

Rhabdosomes attaining several cm in length, widening from 0.8 to 1.00 mm at the level of the  $1^2$  aperture to 2.0–3.5 mm (exceptionally 4.00 mm); the maximum width may be attained in 1 cm from the proximal end or very gradually, almost imperceptibly, with all variations in between; it is generally maintained, although some rhabdosomes tend to narrow distally. Thecae alternate, twelve to sixteen (average 13) proximally, ten to twelve (exceptionally 14–15) distally; they overlap about three-fifths proximally and seven-tenths distally and are inclined about  $30^\circ$ – $35^\circ$  to the axis of the rhabdosome (in specimens in relief), the smaller inclination being typical of proximal thecae. Thecae consist of cylindrical tubes with simple apertures inclined about  $30^\circ$  from the vertical. Apertural excavations are shallow distally, but deeper and more pronounced proximally, and delimited by a selvage merging the thecal aperture with the supragenicular wall. The proximal end bears a mesial spine on the  $1^1$ , the virgella, and one visible sicular spine. The sicula is 2.0–2.5 mm long (as shown by flattened upper Utica specimens of text-figs. 9a–d) and exposed for 1 mm on the obverse side of the rhabdosome (text-fig. 9h). The rhabdosome is circular to ovoid in cross-section (Pl. 2, fig. 8), but if the periderm has collapsed it may have a roughly rectangular cross-section or be so depressed along the axis as to appear concave. A thread-like nema extends from the apex of the prosicula through the rhabdosome and for a short distance beyond. The rhabdosome is aseptate.

*Remarks.* Flattened rhabdosomes of *O. amplexicaulis* present different aspects depending on the direction of compression. Thecae of flattened specimens tend to be

#### EXPLANATION OF PLATE 2

- Figs. 1, 2, 3. *Climacograptus brevis strictus* (Ruedemann). 1, A.M.N.H. 1042. 2, A.M.N.H. 1042A. 3, A.M.N.H. 1042B; all with types of *Climacograptus parvus* Hall. Figs. 1 and 2 are biprofile views showing sharply square thecae, thin virgella, and virgula. Fig. 3 is a three-quarter face view. From the lower Austin Glen Greywacke on the Normans Kill, Kenwood, N.Y. All  $\times 10$ .
- Figs. 4, 5. *Climacograptus parvus* Hall. 5, A.M.N.H. 1042B, shows the 'type', never before figured. 4, A.M.N.H. 1042A, the counterpart and one of the 'types' of *Graptolithus mucronatus* Hall. The counterpart has been figured by Ruedemann (1908, p. 426, text-fig. 388; 1947, pl. 74, fig. 10) who designated it as the holotype, but only the part. Fig. 5 bears a label with 'n.sp.'. From the Austin Glen Greywacke on the Normans Kill, Kenwood, N.Y. Both  $\times 3$ .
- Figs. 7–10. *Orthograptus amplexicaulis* (Hall) from the Trenton Limestone of Middleville, N.Y., except fig. 8 from Trenton Falls. 7, A.M.N.H. 634/1. Proposed lectotype. Rhabdosome in low relief, with proximal end missing, and thecae characteristically alternate, of the orthograptid type. Figured by Hall (1847, pl. 26, figs. 11a–b; 1867, pl. 3, figs. 6, 7).  $\times 6$ . 8, A.M.N.H. 634/1d. Specimen in full relief, circular or ovoid in cross-section; whitened.  $\times 5$ . 9, A.M.N.H. 634/1d. Paratype. Proximal end of thin rhabdosome in low relief.  $\times 6$ . 10, A.M.N.H. 634/1a. Paratype. Broad specimen with periderm collapsed along axis so as to appear concave. Growth lines are pronounced.  $\times 6$ .
- Figs. 6, 11. *Climacograptus pygmaeus* Ruedemann. A.M.N.H. 29259 and 29260. 6, Individual in three-quarter face view in full relief, and of above average length. 11, Obverse side of an individual of average length, in fair relief, and with nearly fully exposed sicula. From the upper Utica Shale on the St. Maurice River, north of Three Rivers, Quebec. Collected by Y. Globensky. Both  $\times 10$ .





1



2



3



CLIMACOGRAPTUS  
HOLL.

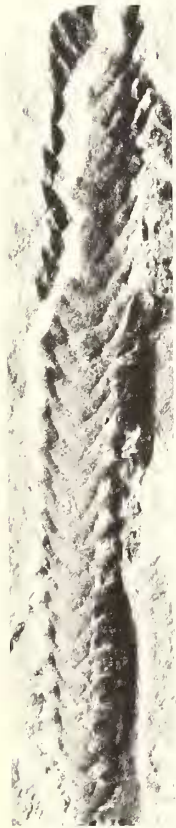
4



5



6



7



8



9



10



11

RIVA, *Climacograptus* and *Orthograptus*

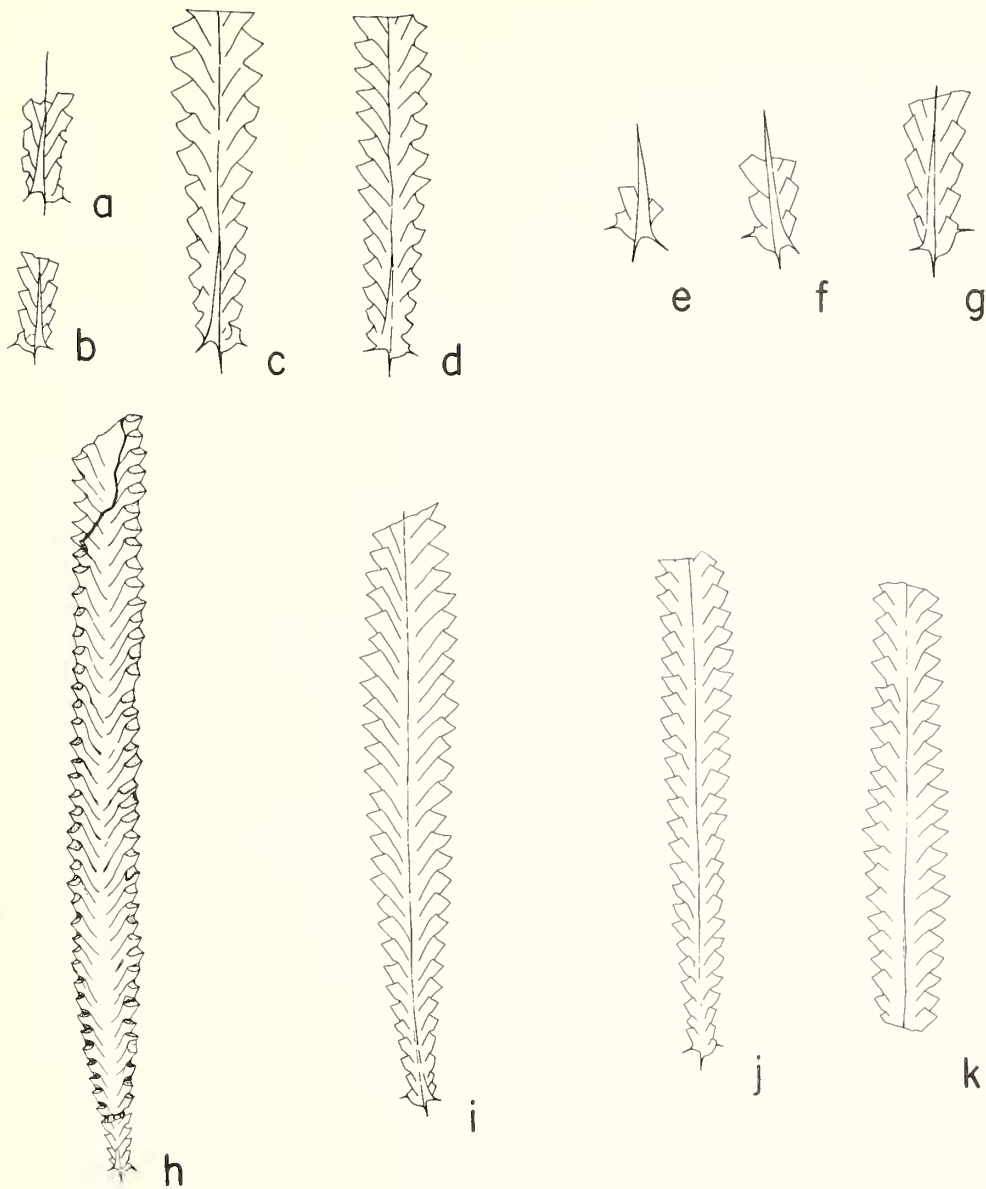


inclined at a higher angle than those of specimens preserved in relief, and this inclination increases noticeably toward the thecal aperture; free ventral walls of distal thecae may form sigmoidal rather than straight outlines (text-figs. 9*c-d*) and those of proximal thecae tend to appear sub-climacograptid because of deeper apertural excavations. This preservation probably accounts for the fact that the species was at one time referred to *Glytograptus* by Ruedemann (1908, p. 361, et seq.). Hall's (1847) first figures of *G. amplexicaule* are rather primitive, showing cone-like structures with thecae appearing as alternating scales. His later figures (1867) are more accurate but still interpretative: one side of the rhabdosome is shown as convex with straight orthograptid thecae, and the other concave with straight but quadrangular thecae. The types (Pl. 2, figs. 7-10) are all distal fragments, except possibly for one (fig. 9), all characterized by simple orthograptid thecae. Their cross-section is roughly quadrangular, somewhat compressed along the centre so as to appear concave on one or both sides. These features are purely preservational and not original or primary. In erecting the genus *Amplexograptus*, Elles and Wood (1907, pp. 218, 221, 258) were apparently influenced by Hall's figures of *D. amplexicaule* which they considered (p. 268) closely related to *A. perexcavatus*, the genotype. This genus has since been redefined on particular thecal characteristics (Bulman 1962), but its name is derived, oddly enough, from a common species of *Orthograptus*.

*Priority of O. amplexicaulis (Hall) over O. truncatus (Lapworth).* Examination of flattened specimens of *O. truncatus* figured by Elles and Wood (1907, pl. 29, figs. 3*a, b, e*) and of additional material from the Hartfell shales—the type specimen itself is apparently lost (O. M. B. Bulman 1970, pers. comm.)—shows that they are morphologically identical to flattened specimens of *O. amplexicaulis* from Canajoharie shales of eastern North America. The specimens figured by Elles and Wood, including the one called 'typical specimen' (pl. 29, fig. 3*a*), lack the proximal end. The proximal end, however, is preserved on several of the Hartfell specimens in the Sedgwick Museum (text-figs. 9*c-g, i, j*) thus allowing a comparison with topotypes of the J. W. Hall collection (text-fig. 9*h*) and flattened specimens from the Utica (text-figs. 9*a-d*). The specimens of *O. truncatus* differ from those of *O. amplexicaulis*, only in degree: they have less closely spaced thecae (10-11 proximally and 9-11 distally) and a longer sicula (from 2.6 to 3.4 mm) than those of *O. amplexicaulis*, but otherwise they are indistinguishable. Such differences may be of subspecific value but hardly suggest a distinct species.

*O. amplexicaulis* was described, figured, and refigured (Hall 1847, 1867) well before *O. truncatus* (Lapworth 1877) and therefore this name has full priority over the latter and should replace it as *chef de file* of this long-ranging group of orthograptids. In North America the name *O. truncatus* was not used until 1960. Ruedemann (1947, p. 412) considered *O. truncatus* identical to, or the 'vicarious' form of, *O. amplexicaulis*, which he, following Elles and Wood's (1907, p. 268) interpretation, referred to *Amplexograptus*. Berry, instead, departed from the American usage by stating (1960, pp. 38, 91-92) that 'specimens at the New York State Museum . . . from Trenton Falls, near Middleville, New York, identified by Ruedemann as *Amplexograptus amplexicaulis* should be referred to the *O. truncatus* group or to *O. truncatus* var. *intermedius*'. The specimens in question are those of the J. W. Hall collection, one of which (N.Y.S.M. 7130) he (op. cit., pl. 17, figs. 4, 5) figured as *O. truncatus* var. *intermedius*, without mentioning its source.

*Stratigraphic and geographic occurrence.* *O. amplexicaulis* occurs sparingly in limestones of the lower part of the Trenton Group (Poland Member of the Denmark Limestone) of the Mohawk Valley of New York and its equivalent of the St. Lawrence Lowlands where it is not uncommon even in upper Trenton (Cobourg) Limestone. It is common in Canajoharie shales of eastern North America, the lower Macasty Shale of Anticosti Island, and part of the Snake Hill Shale of the Hudson River Valley. It is also likely that many specimens identified as *Diplograptus vespertinus* really belong to *O. amplexicaulis*. The differences between *D. vespertinus* and *O. amplexicaulis* are not yet fully understood partly because of the impossibility to recollect from the type locality of the former which is located in the highly sheared and deformed Snake Hill Shale of the Albany, N.Y., area.



TEXT-FIG. 9. *Orthograptus amplexicaulis* (Hall). a-g, Growth stages and proximal ends of *Orthograptus amplexicaulis*. a, b, Growth stages, G.S.C. 26590 and 31738, from the uppermost Utica Shale of the B.M. core (Riva 1969), depth 1405', showing long sicula and squarish thecae;  $\times 5$ . c, d, Immature individuals, G.S.C. 31739 and 32375, with long sicula and broad proximal end. Same depth and core as above;  $\times 5$ . e, f, g, Growth stages of *O. truncatus* (Lapworth) from the Hartfell Shales, Dumfriesshire, Scotland, with a longer sicula than the North American specimens. Sedgwick Museum A19799;  $\times 5$ . h, Topotype, N.Y.S.M. 7128, Middleville, N.Y., figured by Ruedemann (1908, p. 363, fig. 302, pl. 25, fig. 11; 1947, pl. 70, figs. 4, 7), in partial relief with periderm collapsed along axis of rhabdosome;  $\times 3$ . i, j, k, Topotypes of *O. truncatus* (Lapworth), Elles collection, Sedgwick Museum A19799, Hartfell Shales, *D. clingani* Zone, Dumfriesshire, Scotland, for comparison with North America specimens of *O. amplexicaulis*;  $\times 3$ .

*O. amplexicaulis* ranges from the *C. americanus* to within the *C. spiniferus* Zone of the lower Utica. It is found sparingly through the Utica to reappear in great numbers in the uppermost Utica and the lower Lorraine (*C. pygmaeus* to the *C. manitoulinensis* Zones) as a form which is broader proximally than the typical form, although individuals identical to the typical form also occur with it. The names *Diplograptus amplexicaulis* mut. *uticanus*, *Glossograptus quadrimucronatus* mut. *lorrainensis*, and *Diplograptus recurrens* have all been used at the same time by Ruedemann (1925) to describe this late appearance of *O. amplexicaulis* (two of the types of *D. recurrens*, however, are proximal ends of *O. quadrimucronatus* (Hall)), while Parks (1928) named it *Diplograptus montis*. This group obviously needs more study. *O. amplexicaulis* does not occur in the Austin Glen Greywacke as reported by Berry (1962*b*, p. 714), which is almost entirely in the *N. gracilis* Zone, or in collections from the Magog slates (Berry 1962*a*) which are in the *N. gracilis*-*D. multidentis* Zones. The metamorphism of the Magog slates is so advanced as to render specific identifications of all but the most diagnostic biserial graptolites most precarious.

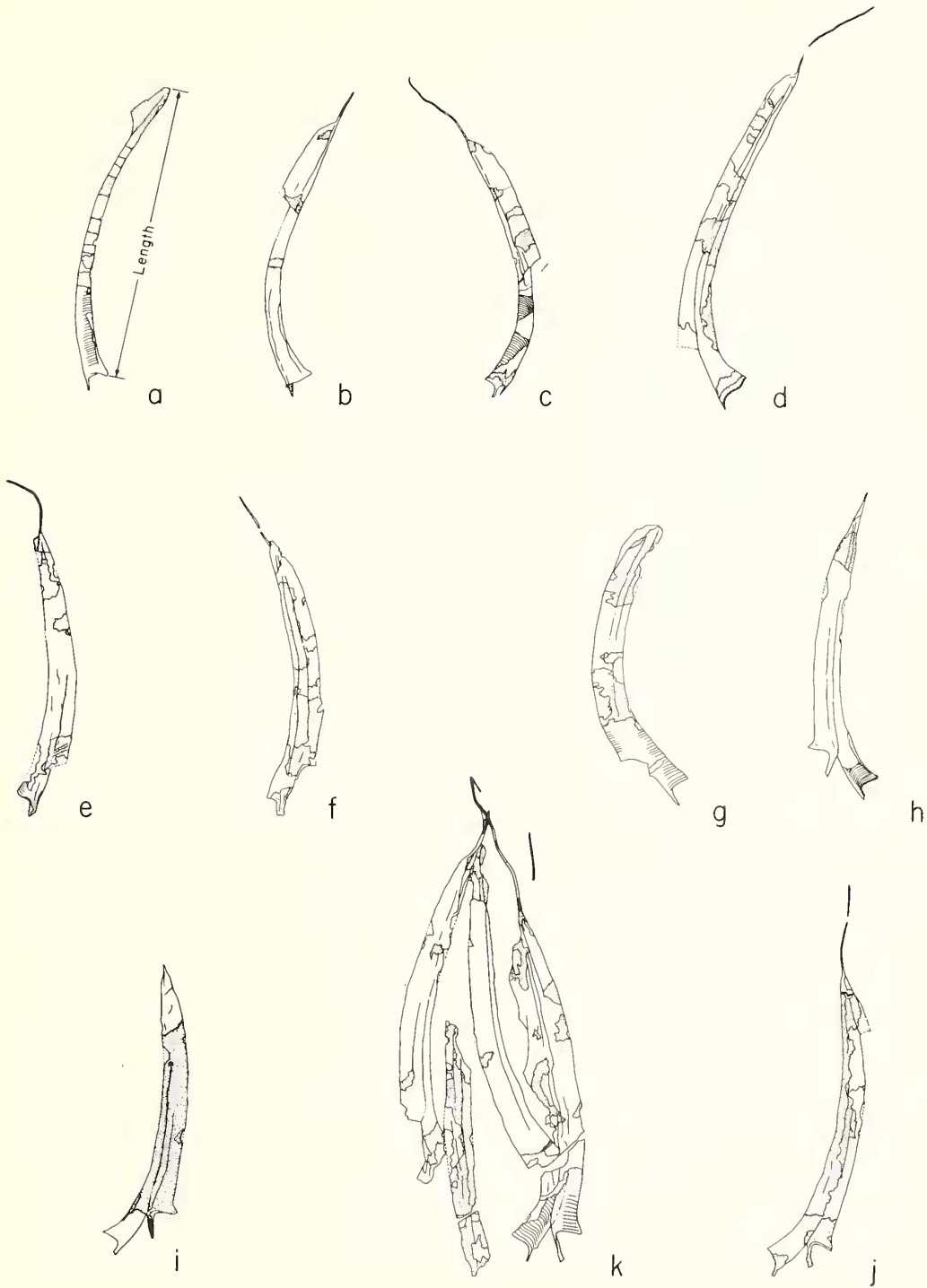
### Genus CORYNOIDES Nicholson, 1867

The morphology and development of two of the most common forms of *Corynoides* have been described in some detail by Bulman (1945, 1947), while Strachan (1949) has described the most common European forms of this genus and at the same time attempted to deal with the synonymy of North American forms, but purely on the basis of Ruedemann's (1947) figures and descriptions. Berry (1960) has fully accepted Strachan's interpretation of the North American species as have Ross and Berry (1963). The writer has made extensive collections of *Corynoides* in the Middle Ordovician of north-eastern North America. In general, two (or three) forms of *Corynoides* occur sparingly in the *N. gracilis* Zone: the short and stubby *C. 'curtus'* mut. *pristinus* Ruedemann and the longer and slender *C. calicularis* Nicholson and *C. curtus* Lapworth. Mut. *pristinus* has been recognized only in the *N. gracilis* Zone and not higher; Strachan (1949, p. 155) considered this form synonymous with the Swedish *C. incurvus* Hadding, but this assignment is questionable since Ruedemann's 1947 figures of mut. *pristinus* are not quite like those of *C. incurvus* as shown by

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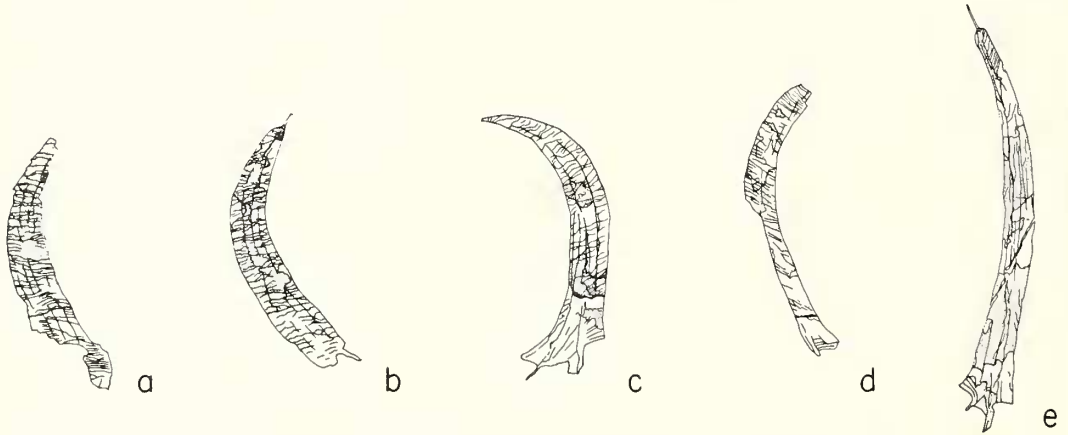
TEXT-FIG. 10. *Corynoides americanus* (Ruedemann). *a*, Syntype, N.Y.S.M. 6971, with sicula and the beginning of th 1. Growth bands shown as imprints in the distal part of the sicula (figured by Ruedemann 1908, pl. 13, fig. 21; 1947, pl. 58, fig. 27);  $\times 10$ . *b*, Syntype, N.Y.S.M. 6964, with sicula largely preserved as impression and th 1 extending part way down the sicula (figured by Ruedemann 1908, p. 240, text-fig. 142);  $\times 10$ . *c*, Syntype, N.Y.S.M. 6966, with portions of periderm preserved with growth bands. Th 1 extends halfway down the sicula (one of three specimens figured by Ruedemann 1908, pl. 13, fig. 4);  $\times 10$ . *d*, Syntype, N.Y.S.M. 6970. Long and strongly curved specimen with th 1 grown almost to the point of divergence from the sicula. The sicular aperture and the virgella are strengthened by a band of secondary material (figured by Ruedemann 1908, pl. 13, fig. 20);  $\times 10$ . *e, f, g*, Poorly preserved specimens of the type collection with th 1 probably grown down to point of divergence. *e*, on N.Y.S.M. 6967 (not previously figured); *f*, on N.Y.S.M. 6966 (not previously figured); *g*, N.Y.S.M. 6966 (figured by Ruedemann 1908, pl. 13, fig. 4); all  $\times 10$ . *h*, Lectotype, N.Y.S.M. 6965. Th 1 is complete after growing down on the convex side of the sicula and diverging from it. Periderm preserved in the distal part of the sicula shows growth lines directed toward the virgellar process; the edge of the aperture is surrounded by a ring of secondary deposits (figured by Ruedemann 1908, p. 240, text-figs. 143-144);  $\times 10$ . *i*, Syntype, N.Y.S.M. 6969, mature individual identical to lectotype (figured by Ruedemann 1908, pl. 13, fig. 19; 1947, pl. 58, fig. 29);  $\times 10$ . *j*, Syntype, N.Y.S.M. 6968, mature individual showing th 1 originating near the point of origin of th 1. The aperture of th 1 is surrounded by a ring of secondary deposits (figured by Ruedemann 1908, pl. 13, fig. 18; 1947, pl. 58, fig. 28);  $\times 10$ . *k*, Group of individuals with nemas tangled in a synrhabdosome, syntype collection, N.Y.S.M. 6967 (figured by Ruedemann 1908, pl. 13, fig. 17; 1947, pl. 58, fig. 26);  $\times 10$ .





Strachan (op. cit., text-fig. 3) and the Swedish form occurs at a much higher level (*D. clingani* Zone) than the North American form (*N. gracilis* Zone) (see Table 1). *C. calicularis* and *C. curtus*, on the other hand, pass up into the *D. multidentis* and *C. americanus* Zones where they occur in great profusion. Strachan (1949) defined *C. calicularis* as consisting of individuals 9 to 13 mm long and *C. curtus* of shorter individuals, 6 to 8 mm long. Both forms are generally straight to slightly curved and consist of a sicula and one or two thecae reaching the sicular aperture. The second theca crosses over to the free side of the sicula near the distal end of the rhabdosome. A third theca appears as a short tube in some individuals which, because of their length, would be referred to *C. calicularis* or *C. curtus*. In our collections, straight to slightly curved individuals, from 4.5 to 9 and 10 mm in length, often occur on the same slab surfaces, although individuals 7–8 mm long tend to predominate. Long and short individuals are morphologically indistinguishable, except for size, which suggests that the present concept on the population of *C. calicularis* should be expanded to comprise all those individuals which, because of size alone, have been separated as *C. curtus*.

Strachan (1949, pp. 155, 157) included as a possible synonym of *C. curtus* a thin and usually strongly curved form which Ruedemann (1947, pp. 359–360) had differentiated as *C. calicularis* var. *americana*. Reasons for this assignment were based on Ruedemann's data (1947) which stated that this form was commonly 6–7 mm long. A restudy of Ruedemann's type material in the New York State Museum reveals that var. *americana* is based on thin and markedly curved individuals, from 4 to 5 mm



TEXT-FIG. 11. *Corynoides comma* Ruedemann, all on the same slab. *a*, *b*, Syntypes, N.Y.S.M. 6972 and 6974, now partly destroyed, originally compressed normally to the length of the rhabdosome as shown by wrinkles across the specimens (figured by Ruedemann 1908, p. 242, text-figs. 145 and 147; 1947, pl. 58, figs. 55, 54); both  $\times 10$ . *c*, Syntype, N.Y.S.M. 6977, strongly curved and thickened by compression normal to the length of the rhabdosome. It could be a short *C. calicularis*, *s.l.*, or *C. americanus* (figured by Ruedemann 1908, pl. 13, fig. 24; 1947, pl. 58, fig. 51);  $\times 10$ . *d*, Syntype, N.Y.S.M. 6975, strongly curved and compressed diagonally to the length of the rhabdosome showing the sicula and partly grown th 1 (figured by Ruedemann 1908, p. 242, text-fig. 148);  $\times 10$ . *e*, Syntype, N.Y.S.M. 6976, longest specimen, slightly curved and compressed normally to its length. It consists of the sicula and th 1 reaching the sicular aperture. It could be a deformed *C. calicularis*, *s.l.* (figured by Ruedemann 1908, pl. 13, fig. 22; 1947, pl. 58, fig. 53);  $\times 10$ .

long (and not 6–7 mm as stated by Ruedemann whose figures on pl. 58 are  $\times 8$  and not  $\times 5$ ) and consisting of a sicula and a theca which does not reach the sicular aperture. This form is quite distinct from all those that could be referred to *C. calicularis*, *sensu lato*, and therefore it is considered here a distinct species, *C. americanus*. This species is quite developed in the lower Canajoharie shales of the Mohawk Valley and the St. Lawrence Lowlands and to a much lesser extent in the Snake Hill Shale of the Hudson River Valley and the Macasty Shale of Anticosti Island. It is a form endemic to north-eastern North America. On the other hand, the types of *C. comma* (text-fig. 11) consist of deformed individuals shortened and bent by compression normal to the length of the rhabdosome (text-figs. 11*a–d*) or parallel to it (text-fig. 11*e*). Most of these individuals possibly belong to *C. americanus* and some to *C. calicularis s.l.*, but the specimens are too deteriorated to permit definite identifications. The type locality (Ruedemann 1901, p. 519) was at an accumulation of dump material from the Hudson River and is now fully overgrown and inaccessible, but the fauna reported by Ruedemann (1908, p. 242) suggests the *C. americanus* Zone. It is felt here that the ends of taxonomy are best served by ignoring the existence of this species.

*C. ultimus* from the middle part of the Utica Shale of the Mohawk Valley has not been restudied.

### *Corynoides americanus* (Ruedemann)

Text-fig. 10

- 1908 *Corynoides curtus* Lapworth; Ruedemann, pp. 240–241, text-figs. 140–144, pl. 13, figs. 4, 17–21.  
 ?1908 *Corynoides curtus* var. *comma* Ruedemann, p. 242, text-figs. 145–148, pl. 13, figs. 5, 22–24.  
 1947 *Corynoides calicularis* var. *americana* Ruedemann, pp. 359–360, pl. 59, figs. 26–29.  
 ?1947 *Corynoides comma* Ruedemann, p. 360, pl. 58, figs. 49–55.  
 1949 *Corynoides curtus* Lapworth; Strachan (*partim*), pp. 155, 157, 158.  
 ?1949 *Corynoides comma* Ruedemann; Strachan, p. 155.

*Proposed lectotype.* N.Y.S.M. 6965 (Ruedemann 1908, text-figs. 143, 144) from the Snake Hill Shale in a quarry (now partly filled) in the Albany Rural Cemetery (section 23), Albany, N.Y. The quarry is about 400 feet north of the tomb of U.S. President Arthur.

*Other material.* N.Y.S.M. 6964, 6966–6971, all part of the syntypic series in the N.Y. State Museum, and all from the Snake Hill Shale in the Rural Cemetery at Albany, N.Y. In addition the writer has extensive collections from the lower Canajoharie Shale, the Cloridorme Formation, and the basal Macasty Shale.

*Description.* Rhabdosome thin and short, consisting of a gently to strongly curved sicula, from 3.5 to 6.5 mm long (the length is measured as indicated on text-fig. 10*a*), and of a theca originating near the apex of the sicula and growing down on the convex side to about 0.4–0.5 mm from the sicular aperture where it diverges from the sicula. A second theca is seen in some specimens to form near the apex of the first theca (text-fig. 10*j*). Both the sicula and th 1 develop lamelliform virgellar processes. Growth bands are recognizable in pyritized specimens and they characteristically curve forwards toward the virgellar structure (text-figs. 10*a, c, g, h, k*). The edge of the sicular aperture and the virgella are reinforced by secondary thickening (text-figs. 10*d, h*) as are the aperture and the virgellar structure of the first theca (text-fig. 10*j*). In the type material, the rhabdosome attains a maximum width of 0.5–0.6 mm at the point of divergence of th 1 from the sicula.



*Remarks.* Siculae of this species possess a long nema which may, exceptionally, become tangled as synrhabdosomes as is well shown by one of Ruedemann's types (text-fig. 10k). *C. americanus* can easily be differentiated from *C. calicularis*, *sensu lato* by its marked curvature and the thinness of the rhabdosome (1.0–1.4 mm in *C. calicularis*, versus half that width in *C. americanus*). Morphological differences are even more pronounced: in *C. calicularis*, both thecae grow down to just about the level of the sicular aperture while in *C. americanus* the first theca (and the only theca to grow to full size) stops short of the sicular aperture and diverges from it.

*Stratigraphic and geographic occurrence.* *C. americanus* occurs in great profusion and to the exclusion of any other *Corynoides* in the lower Canajoharie shales of the Mohawk Valley of New York (*G. americanus* Zone), but near the middle part of the Canajoharie it is replaced by long and short individuals of *C. calicularis s.l.*, apparently making their last appearance before their demise. *C. americanus* occurs also, but to a lesser degree, in the folded Snake Hill Shale of the Hudson River Valley (the types came from outcrops referred to this unit). *C. americanus* has been recognized in Canajoharie shales from boreholes in the Lake Champlain area of Quebec (Lozo-Joseph 2 core of Riva 1969), and from the base of the Macasty Shale of Anticosti Island (3170-ft. level of the L.G.P.L. core of Riva 1969), and from parts of the Cloridorme Formation of Gaspé (Riva 1968). *C. calicularis*, however, is the dominant *Corynoides* of the basal Macasty and the Cloridorme. The unquestioned concentration of *C. americanus* in the lower Canajoharie of the Mohawk Valley suggests that this form is essentially endemic to that region where it developed from a *calicularis* stock during the early phases of the Utica Shale invasion of the continental platform in Middle Ordovician time at the onset of the Taconic orogeny.

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